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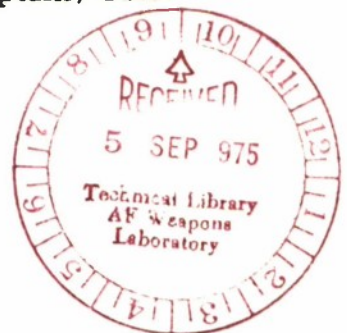
BOLLING AFB STACK EMISSION EVALUATION
BOLLING AFB DC

By

Marlin L. Sweigart, Captain, USAF

July 1975

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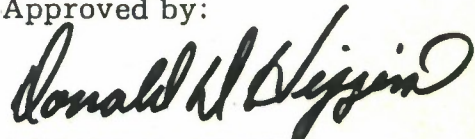
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ABSTRACT

This report presents the results of particulate emission testing done on a single oil fired steam boiler at Bolling AFB, Washington DC. Testing was done at three different heat input loadings as requested by the Washington District Commission. Particulate emissions varied from 0.055 pounds/Million British Thermal Units (lbs/MBTU) to 0.080 lbs/MBTU. The unit was found to be in compliance with District of Columbia standards which ranged from 0.072 lbs/MBTU to 0.086 lbs/MBTU. Emission data are compared with Environmental Protection Agency (EPA) published emission factors for similar units.

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SECTION I

INTRODUCTION

1. Background: The Central Heating Plant, Building 18 at Bolling AFB, presently contains two steam boilers. In June 1974, both of these boilers were emission tested by Particle Data Laboratories, Ltd., of Elmhurst, Illinois (Appendix D) and found to be in violation of Washington DC particulate emission standards. During these tests the boilers were utilizing #6 fuel oil. In March 1975, the Bolling Civil Engineer approved a modified plan which would replace the existing steam boilers with hot water generators and steam converters. As of May 1975, two hot water generators were installed, the third should be installed by November 1976. During the interim, one of the old boilers will be needed to provide sufficient steam. District of Columbia representatives suggested that base personnel convert this steam boiler to #4 fuel oil in lieu of #6 and retest it to determine if this change would produce emissions which would meet present District environmental standards. In May 1975, at the request of the DCS/Civil Engineering, Headquarters Command USAF, Bolling AFB, the boiler was retested by USAF Environmental Health Laboratory, McClellan AFB (USAFEHL-M) personnel.

2. Purpose: The primary purpose of this study was to test compliance of this unit with Washington DC particulate emission standards.

3. Personnel:

a. USAFEHL-M Survey Personnel:

(1) Maj Ronald D. Burnett, Chief, Occupational Safety & Health Engineering Division.

(2) Capt Marlin L. Sweigart, Project Engineer, Autovon 633-3070.

(3) Sgt William Conway, Environmental Health Technician.

(4) Airman Steven Brennan, Environmental Health Technician.

b. Bolling AFB Personnel Contacted:

(1) Col Thayer W. Allison, Base Civil Engineer.

(2) Mr Jeff Peck, Project Officer, Base Civil Engineer, Autovon 297-4456.

(3) MSgt Russel Lichnovsky, Central Base Heating Plant Manager.

SECTION II

UNIT DESCRIPTION AND OPERATION

The unit tested is the #5 steam boiler in the Central Base Heating Plant. The boiler was manufactured by Titusville in 1941. Rated output capacity is 35,810 pounds of steam per hour, and rated heat input capacity was calculated at 44 MBTU/hr. It has a rotary cup fuel injection system and utilizes an induced draft fan. The fan is a constant speed 40 HP unit running at 1175 RPM. The unit contains no particulate collection devices. Figure 1 shows the general dimensions of the stack.

SECTION III

SAMPLING METHOD AND PROCEDURES

1. General:

a. Except for deviations specified below, EPA methods and procedures given in the Appendix to Title 40, Code of Federal Regulations, Part 60 (40 CFR 60) for performance testing of new stationary sources were used to test the boiler (Appendix A).

b. The EPA sampling methods are not listed as approved methods of stationary particulate sampling in District of Columbia regulations. However, the District Commission requested the use of EPA methods and procedures in this test.

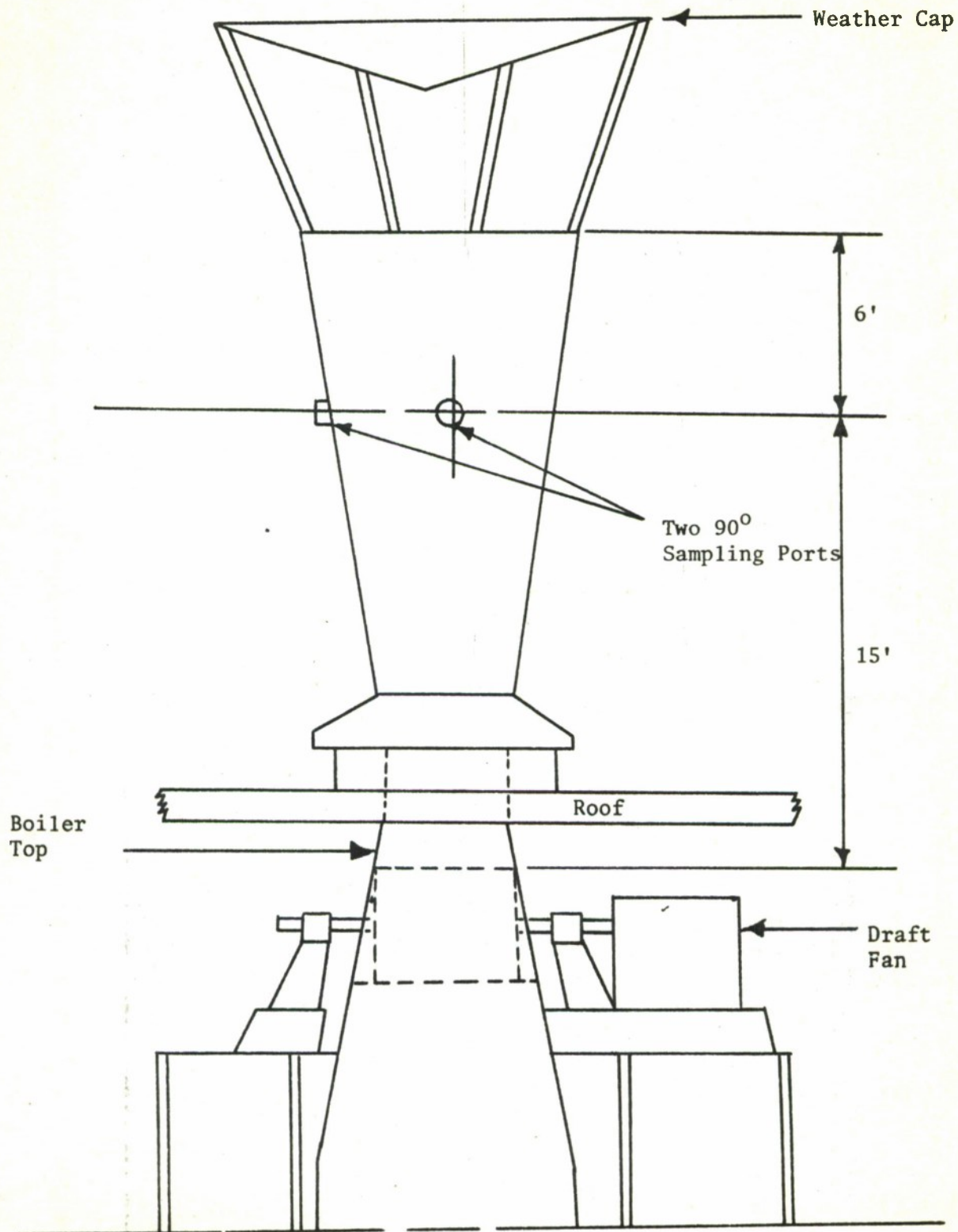
2. Deviations:

a. Because of the large stack diameter and nearness of an upstream disturbance, 40 CFR 60 specified a 36 point traverse. Two preliminary traverses were run; one with 36 points and one with 12 points. A comparison of these profiles indicated that an unbiased sample could be collected by sampling only 12 points. Therefore, 12 points were sampled at 10 minutes per point in each of the six runs.

b. A preliminary moisture determination was not done. Instead, a dry gas fraction of 0.95 was assumed to establish isokinetic sampling

FIGURE I

BOILER STACK #5 AT BOLLING AFB DC



conditions on the first run. The actual moisture content of the stack gas was determined from water collected during this run and this value was used in the next run to establish isokinetic conditions. This procedure was followed at each of the three input loadings. Moisture contents computed for the runs were used in all final calculations including verification of isokinetic sampling.

c. As requested by the District Commission, two sampling runs were made at each of three different boiler loads (Ref. 3). These loads were classified as low, nominal and high input (maximum operating) capacities. The actual particulate emissions were computed as the average of the two runs at each loading.

3. Additional Procedures:

a. Carbon dioxide (CO_2), and oxygen (O_2) gas readings were taken with an Orsat Analyzer. A minimum of four readings were taken during each run. The average of these readings was used in all calculations. An initial carbon monoxide (CO) reading indicated an insignificant amount of CO in the stack gas.

b. Burner fuel flow readings were recorded every 15 minutes and the average flow was used in calculating the total fuel used during each test.

c. Data were reduced in accordance with procedures found in 40 CFR 60. Only reduced data are presented in the main report. Raw data for the six particulate runs are presented in Appendix C. All calculations were done on a Hewlett-Packard 9810A Programmable Calculator.

SECTION IV

APPLICABLE EMISSION STANDARDS

District of Columbia particulate emission standards are found in District regulations, Section 8-2: 708, Fuel Burning Particulate Emission (Appendix B). Allowable emissions for installations with a total heat input between 3.5 and 10,000 MBTU/hr are determined by the equation $E = 0.17455 H^{-0.23522}$ where E equals particulate emissions in lbs/MBTU and H equals the total heat input in MBTU/hr. For a 20 MBTU/hr boiler the allowable particulate emissions are 0.086 lbs/MBTU. The specific allowable particulate emissions at each of the heat input loadings tested are discussed in Section VI.

SECTION V

RESULTS

1. Sampling Parameters: The reduced data from the six sampling runs are presented in Table I. The CO_2 and O_2 analyses were done with an Orsat instrument. As the data in Table I indicate, the stack temperature, flow, and moisture content all increased as the boiler operating level increased. In runs five and six the boiler was operating at its maximum capacity. All runs were done within 10% of isokinetic conditions as specified by 40 CFR 60. The percent by volume of excess air decreased considerably when the operating level was increased. This was expected since the induced draft fan is a constant speed type.

2. Particulate Data: Particulate emission data from the six tests are presented in Table II. Runs two and four were the low boiler loading tests, runs one and three were the nominal boiler loading runs and runs five and six were the high boiler loading tests. As the data in Table II indicate, the difference between the low and nominal input loadings was very small. One low run, run number four, was conducted while the boiler was in single burner operation.

SECTION VI

DISCUSSION

1. Actual Emissions: The averages of the runs conducted at each of the three input capacity loadings were below the maximum allowable District of Columbia particulate emission standards. The emissions in lbs/MBTU were lowest when the boiler was operating at its highest input capacity. At the lower loadings, the emissions approached the standard but were still within compliance. The lower particulate emissions in pounds/MBTU at the higher loadings was typical since boilers generally operate more efficiently near their maximum loading capacity.

2. Emission Factors: The average particulate emissions at each of the three loadings in pounds of particulate per 1000 gallons ($\text{lbs}/10^3 \text{ gal}$) of fuel burned were computed. The low loading tests emitted 11.2 $\text{lbs}/10^3 \text{ gal}$, the nominal loadings 12.2 $\text{lbs}/10^3 \text{ gal}$ and the high loadings 7.91 $\text{lbs}/10^3 \text{ gal}$ of fuel. The BTU content of the #4 fuel oil blend burned was 143,000 BTU/gallon as specified by Stuart Petroleum of Washington DC, the fuel supplier (Ref. 5). The emission factor published by the

TABLE I
PARTICULATE EMISSION SAMPLING DATA
BOLLING AFB DC

Run	Operating Level		Stack Gas			Gaseous Emissions			Isokinetics	Excess Air	
	Input	% of Max	Temp	Flow	H ₂ O	Volume %(1)				%	Volume %
	MBTU/hr	Capacity	oF	scfm	%	CO ₂	O ₂	N ₂			
1	22	50.0	400	11,591	5.3	4.7	13.2	82.1	93		157
2	21	47.7	400	10,113	5.4	3.9	14.9	81.1	95		232
3	22.1	50.2	400	7,773	5.0	4.8	13.9	81.3	99		185
4	20	45.4	382	8,565	5.6	3.8	14.8	81.4	96		221
5	43.8	99.5	510	12,509	6.9	6.8	11.2	82.1	96		106
6	43.3	98.4	518	12,282	6.5	6.8	12.2	81.1	96		132

(1) Orsat Analysis

TABLE II

STACK PARTICULATE EMISSIONS
BOLLING AFB DC

1. Boiler Operating at Low Loading									
Run	Operating Level		Actual Particulate Emissions		Actual Particulate Emissions		Allowable Particulate Emissions		
	Input MBTU/hr	% of Max Capacity	Pounds/hr		Pounds/MBTU		Pounds/MBTU		
2	21	47.7	1.54		0.073		0.086		
4	20	45.4	1.69		0.080		0.086		
Average					0.077		0.086		
2. Boiler Operating at Nominal Loading									
Run	Operating Level		Actual Particulate Emissions		Actual Particulate Emissions		Allowable Particulate Emissions		
	Input MBTU/hr	% of Max Capacity	Pounds/hr		Pounds/MBTU		Pounds/MBTU		
1	22	50.0	1.54		0.070		0.084		
3	22.1	50.2	2.20		0.090		0.084		
Average					0.080		0.084		
3. Boiler Operating at High Loading									
Run	Operating Level		Actual Particulate Emissions		Actual Particulate Emissions		Allowable Particulate Emissions		
	Input MBTU/hr	% of Max Capacity	Pounds/hr		Pounds/MBTU		Pounds/MBTU		
5	43.8	99.5	2.42		0.055		0.072		
6	43.3	98.4	2.39		0.055		0.072		
Average					0.055		0.072		

Environmental Protection Agency for a unit of comparable size burning a fuel with a similar BTU/gal content is 17 lbs/10³ gal (Ref. 6). The emissions collected were probably lower than the EPA factors because the tested unit utilizes a rotary cup fuel injection system. These units are very efficient especially at high capacity loadings. The EPA figure is calculated to include all types of industrial and commercial units and is a slightly high estimate for units with rotary cup combustion systems. The data therefore compare favorably with EPA emission factors and also with previous USAFEHL-M data from emission tests of similar units (Ref. 7 & 8).

3 Particulate Reduction: Particulate emission testing conducted by Particle Data Laboratories of Elmhurst, Illinois prior to the change from #6 to #4 fuel oil showed average emissions of 0.175 lbs/MBTU on the #5 boiler. These tests were conducted while the boiler was operating at very low input heat loadings of from 15.123 MBTU/hr to 16.940 BTU/hr. After the boiler was cleaned and the fuel oil was changed from #6 to #4, emissions decreased to an average of 0.078 lbs/MBTU for testing done at input heat loadings of approximately 21 MBTU/hr. The combination of cleaning, fuel conversion, and a slightly higher test loading produced a 45% decrease in boiler particulate emissions. EPA estimates that fuel conversion alone could reduce emissions as much as 35% (Ref. 4).

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions: The conversion from #6 to #4 fuel oil in conjunction with the thorough cleaning of boiler #5 produced particulate emissions which do not violate current District of Columbia standards.

2. Recommendations:

- a. Continued use of #4 fuel oil in boiler #5.
- b. Continued cleaning and timely maintenance practices on boiler #5.

REFERENCES

1. Title 40, Code of Federal Regulations, Part 60, Appendix I, Revised July 1973.
2. Boiler Emission Tests, Bolling AFB, 19 June 75, Prof. Report, Particle Data Laboratories, Ltd., Elmhurst IL.
3. Personal Communication; Letter from Col M. E. Maresca, DCS/Civil Engineering, Bolling AFB to USAFEHL-McClellan AFB CA.
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7. Jackson, J. W., Boiler and Incinerator Emissions Study, USAF Academy, CO., Prof. Report No 74M-11, USAF Environmental Health Laboratory, McClellan AFB, July 1974.
8. Jackson, J.W. et al, Effects on Emissions of Particulates Hydrocarbons, Nitrogen Oxides, Lead and Iron From Using Waste POL As A Supplement To Heating Plant Fuel, Prof. Report, USAF Environmental Health Laboratory, McClellan AFB, June 1975.

APPENDIX A

APPENDIX TO 40 CFR 60

App. A

Title 40—Protection of Environment

In terms of either R_{DV} (metric units: mg dry sludge/liter sludge charged or English units: lb/ft³) or R_{DM} (metric units: mg dry sludge/mg sludge charged or English units: lb/lb).

(3) Determine the quantity of dry sludge per unit sludge charged in terms of either R_{DV} or R_{DM} .

(i) If the volume of sludge charged is used:

$$S_D = (60 \times 10^{-3}) \frac{R_{DV} S_V}{T} \text{ (Metric Units)}$$

or

$$S_D = (8.021) \frac{R_{DV} S_V}{T} \text{ (English Units)}$$

where:

S_D = average dry sludge charging rate during the run, kg/hr (English units: lb/hr).

R_{DV} = average quantity of dry sludge per unit volume of sludge charged to the incinerator, mg/l (English units: lb/ft³).

S_V = sludge charged to the incinerator during the run, m³ (English units: gal).

T = duration of run, min (English units: min).

60×10^{-3} = metric units conversion factor, 1-kg-min/m³-mg-lr.

8.021 = English units conversion factor, ft³-min/gal-hr.

(ii) If the mass of sludge charged is used:

$$S_D = (60) \frac{R_{DM} S_M}{T} \text{ (Metric or English Units)}$$

where:

S_D = average dry sludge charging rate during the run, kg/hr (English units: lb/hr).

R_{DM} = average ratio of quantity of dry sludge to quantity of sludge charged to the incinerator, mg/mg (English units: lb/lb).

S_M = sludge charged during the run, kg (English units: lb).

T = duration of run, min (Metric or English units).

60 = conversion factor, min/hr (Metric or English units).

(d) Particulate emission rate shall be determined by:

$$C_{ew} = C_a Q_a \text{ (Metric or English Units)}$$

where:

C_{ew} = particulate matter mass emissions, mg/hr (English units: lb/hr).

C_a = particulate matter concentration, mg/m³ (English units: lb/dscf).

Q_a = volumetric stack gas flow rate, dscm/hr (English units: dscf/hr). Q_a and C_a shall be determined using Methods 2 and 5, respectively.

(e) Compliance with § 60.152(a) shall be determined as follows:

$$C_{ds} = (10^{-3}) \frac{C_{ew}}{S_D} \text{ (Metric Units)}$$

or

$$C_{ds} = (2000) \frac{C_{ew}}{S_D} \text{ (English Units)}$$

where:

C_{ds} = particulate emission discharge, g/kg dry sludge (English units: lb/ton dry sludge).

10^{-3} = Metric conversion factor, g/mg.

2000 = English conversion factor, lb/ton.

[39 FR 9319, Mar. 8, 1974; 39 FR 13776, Apr. 17, 1974; 39 FR 15396, May 3, 1974]

APPENDIX A—REFERENCE METHODS

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. Principle and Applicability.

1.1 Principle. A sampling site and the number of traverse points are selected to aid in the extraction of a representative sample.

1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the New Source Performance Standards. Unless otherwise specified, this method is not intended to apply to gas streams other than those emitted directly to the atmosphere without further processing.

2. Procedure.

2.1 Selection of a sampling site and minimum number of traverse points.

2.1.1 Select a sampling site that is at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, contraction, or visible flame. For rectangular cross section, determine an equivalent diameter from the following equation:

$$\text{equivalent diameter} = 2 \left(\frac{(\text{length})(\text{width})}{\text{length} + \text{width}} \right)$$

equation 1-1

2.1.2 When the above sampling site criteria can be met, the minimum number of traverse points is twelve (12).

2.1.3 Some sampling situations render the above sampling site criteria impractical. When this is the case, choose a convenient sampling location and use Figure 1-1 to de-

termine the minimum number of traverse points. Under no conditions should a sampling point be selected within 1 inch of the stack wall. To obtain the number of traverse points for stacks or ducts with a diameter less than 2 feet, multiply the number of points obtained from Figure 1-1 by 0.67.

2.1.4 To use Figure 1-1 first measure the distance from the chosen sampling location to the nearest upstream and downstream disturbances. Determine the corresponding number of traverse points for each distance

from Figure 1-1. Select the higher of the two numbers of traverse points, or a greater value, such that for circular stacks the number is a multiple of 4, and for rectangular stacks the number follows the criteria of section 2.2.2.

2.2 Cross-sectional layout and location of traverse points.

2.2.1 For circular stacks locate the traverse points on at least two diameters according to Figure 1-2 and Table 1-1. The traverse axes shall divide the stack cross section into equal parts.

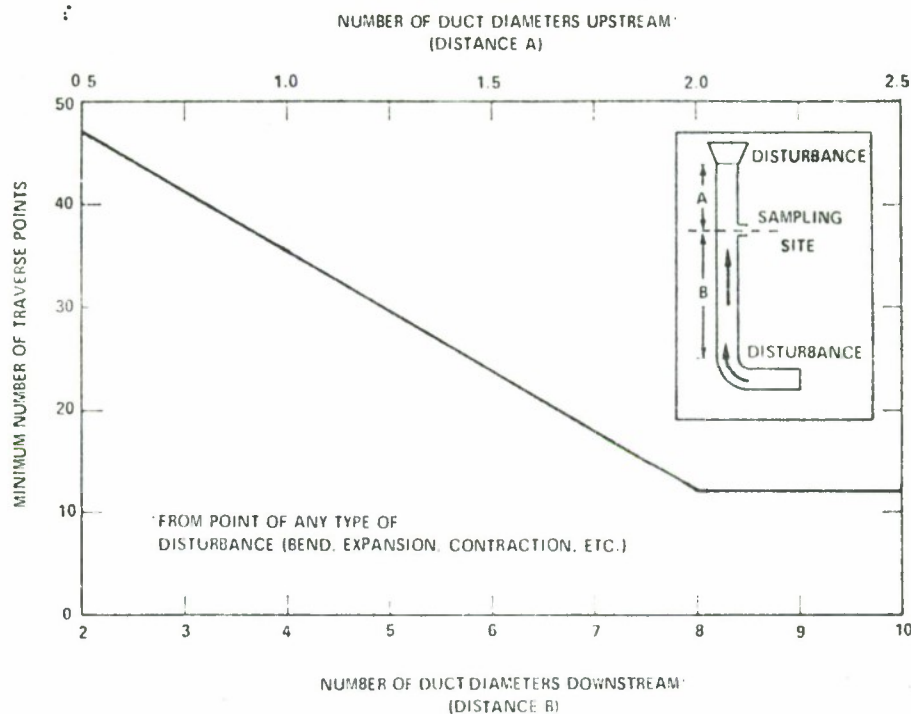


Figure 1-1. Minimum number of traverse points.

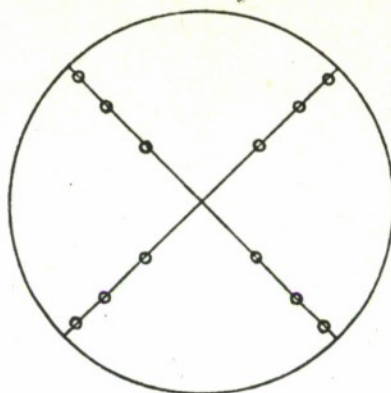


Figure 1-2. Cross section of circular stack divided into 12 equal areas, showing location of traverse points at centroid of each area.

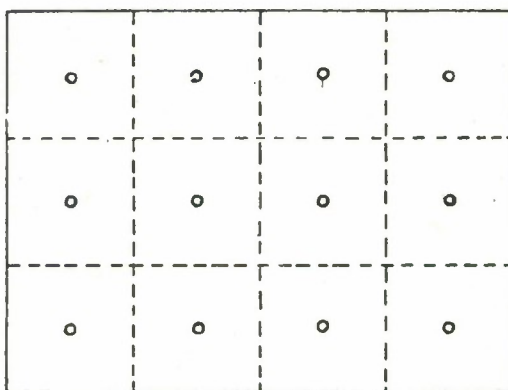


Figure 1-3. Cross section of rectangular stack divided into 12 equal areas, with traverse points at centroid of each area.

Table 1-1. Location of traverse points in circular stacks
(Percent of stack diameter from inside wall to traverse point)

Traverse point number on a diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10					97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.9	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												95.8
24												98.9

2.2.2 For rectangular stacks divide the cross section into as many equal rectangular areas as traverse points, such that the ratio of the length to the width of the elemental areas is between one and two. Locate the traverse points at the centroid of each equal area according to Figure 1-3.

3. References.

Determining Dust Concentration in a Gas Stream, ASME Performance Test Code #27, New York, N.Y., 1957.

Devorkin, Howard, et al., Air Pollution Source Testing Manual, Air Pollution Control District, Los Angeles, Calif., November 1963.

Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases, Western Precipitation Division of Joy Manu-

facturing Co., Los Angeles, Calif. Bulletin WP-50, 1968.

Standard Method for Sampling Stacks for Particulate Matter, In: 1971 Book of ASTM Standards, Part 23, Philadelphia, Pa. 1971, ASTM Designation D-2928-71.

METHOD 2—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. Principle and applicability.

1.1 Principle. Stack gas velocity is determined from the gas density and from measurement of the velocity head using a Type S (Stauscheibe or reverse type) pitot tube.

1.2 Applicability. This method should be applied only when specified by the test pro-

cedures for determining compliance with the New Source Performance Standards.

2. Apparatus.

2.1 Pitot tube—Type S (Figure 2-1), or equivalent, with a coefficient within $\pm 5\%$ over the working range.

2.2 Differential pressure gauge—Inclined manometer, or equivalent, to measure velocity head to within 10% of the minimum value.

2.3 Temperature gauge—Thermocouple or equivalent attached to the pitot tube to measure stack temperature to within 1.5% of the minimum absolute stack temperature.

2.4 Pressure gauge—Mercury-filled U-tube manometer, or equivalent, to measure stack pressure to within 0.1 in. Hg.

2.5 Barometer—To measure atmospheric pressure to within 0.1 in. Hg.

2.6 Gas analyzer—To analyze gas composition for determining molecular weight.

2.7 Pitot tube—Standard type, to calibrate Type S pitot tube.

3. Procedure.

3.1 Set up the apparatus as shown in Figure 2-1. Make sure all connections are tight and leak free. Measure the velocity head and temperature at the traverse points specified by Method 1.

3.2 Measure the static pressure in the stack.

3.3 Determine the stack gas molecular weight by gas analysis and appropriate calculations as indicated in Method 3.

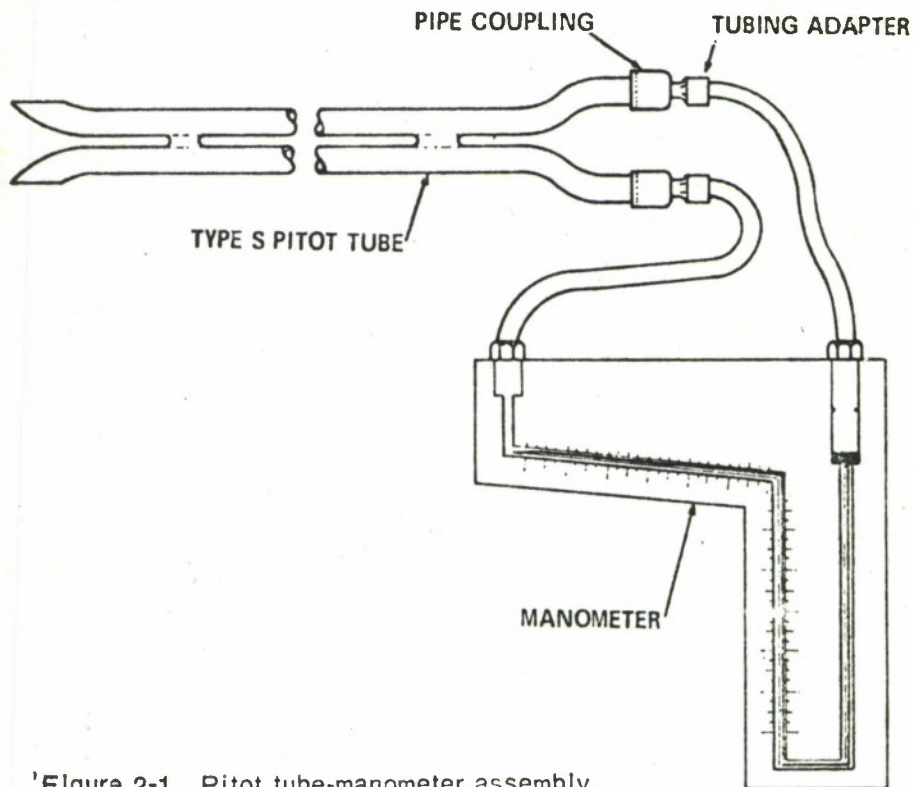


Figure 2-1. Pitot tube-manometer assembly.

4. Calibration.

4.1 To calibrate the pitot tube, measure the velocity head at some point in a flowing gas stream with both a Type S pitot tube and a standard type pitot tube with known coefficient. Calibration should be done in the laboratory and the velocity of the flowing gas stream should be varied over the normal working range. It is recommended that the calibration be repeated after use at each field site.

4.2 Calculate the pitot tube coefficient using equation 2-1.

$$C_{p, \text{test}} = C_{p, \text{std}} \sqrt{\frac{\Delta p_{\text{std}}}{\Delta p_{\text{test}}}} \quad \text{equation 2-1}$$

where:

$C_{p, \text{test}}$ = Pitot tube coefficient of Type S pitot tube.

$C_{p, \text{std}}$ = Pitot tube coefficient of standard type pitot tube (if unknown, use 0.99).

Δp_{std} = Velocity head measured by standard type pitot tube.

Δp_{test} = Velocity head measured by Type S pitot tube.

4.3 Compare the coefficients of the Type S pitot tube determined first with one leg and then the other pointed downstream. Use the pitot tube only if the two coefficients differ by no more than 0.01.

5. Calculations.

Use equation 2-2 to calculate the stack gas velocity.

$$(V_s)_{\text{avg}} = K_p C_p (\sqrt{\Delta p})_{\text{avg}} \sqrt{\frac{(T_s)_{\text{avg}}}{P_s M_s}} \quad \text{Equation 2-2}$$

where:

$(V_s)_{\text{avg}}$ = Stack gas velocity, feet per second (f.p.s.).

$K_p = 85.48 \frac{\text{ft.}}{\text{sec.}} \left(\frac{\text{lb.}}{\text{lb. mole} \cdot ^\circ \text{R}} \right)^{1/2}$ when these units are used.

C_p = Pitot tube coefficient, dimensionless.

$(T_s)_{\text{avg}}$ = Average absolute stack gas temperature, $^\circ \text{R}$.

$(\sqrt{\Delta p})_{\text{avg}}$ = Average velocity head of stack gas, inches H_2O (see Fig. 2-2).

P_s = Absolute stack gas pressure, inches Hg.

M_s = Molecular weight of stack gas (wet basis) lb./lb.-mole.

$M_d(1-B_{wv}) + 18B_{wv}$

M_d = Dry molecular weight of stack gas (from Method 3).

B_{wv} = Proportion by volume of water vapor in the gas stream (from Method 4).

Figure 2-2 shows a sample recording sheet for velocity traverse data. Use the averages in the last two columns of Figure 2-2 to determine the average stack gas velocity from Equation 2-2.

Use Equation 2-3 to calculate the stack gas volumetric flow rate.

$$Q_s = 3600 (1 - B_{wv}) V_s A \left(\frac{T_{\text{std}}}{(T_s)_{\text{avg}}} \right) \left(\frac{P_s}{P_{\text{std}}} \right) \quad \text{Equation 2-3}$$

where:

Q_s = Volumetric flow rate, dry basis, standard conditions, ft.³/hr.

A = Cross-sectional area of stack, ft.²

T_{std} = Absolute temperature at standard conditions 539 $^\circ \text{R}$.

P_{std} = Absolute pressure at standard conditions, 29.92 inches Hg.

6. References.

Mark, L. S., Mechanical Engineers' Handbook, McGraw-Hill Book Co., Inc., New York, N.Y., 1951.

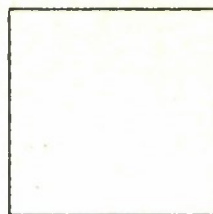
Perry, J. H., Chemical Engineers' Handbook, McGraw-Hill Book Co., Inc., New York, N.Y., 1960.

Shigehara, R. T., W. F. Todd, and W. S. Smith. Significance of Errors in Stack Sampling Measurements. Paper presented at the Annual Meeting of the Air Pollution Control Association, St. Louis, Mo., June 14-19, 1970.

Standard Method for Sampling Stacks for Particulate Matter, in: 1971 Book of ASTM Standards, Part 23, Philadelphia, Pa., 1971, ASTM Designation D-2928-71.

Vennard, J. K., Elementary Fluid Mechanics, John Wiley & Sons, Inc., New York, N.Y., 1947.

OPERATORS



**SCHEMATIC OF STACK
CROSS SECTION**

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Figure 2-2. Velocity traverse data.

**METHOD 3—GAS ANALYSIS FOR CARBON DIOXIDE,
EXCESS AIR, AND DRY MOLECULAR WEIGHT**

1. Principle and applicability.

1.1 Principle. An integrated or grab gas sample is extracted from a sampling point and analyzed for its components using an Orsat analyzer.

1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the New Source Performance Standards. The test procedure will indicate whether a grab sample or an integrated sample is to be used.

2. Apparatus.

2.1 Grab sample (Figure 3-1).

2.1.1 Probe—Stainless steel or Pyrex¹ glass, equipped with a filter to remove particulate matter.

2.1.2 Pump—One-way squeeze bulb, or equivalent, to transport gas sample to analyzer.

2.2 Integrated sample (Figure 3-2).

2.2.1 Probe—Stainless steel or Pyrex¹ glass, equipped with a filter to remove particulate matter.

2.2.2 Air-cooled condenser or equivalent—To remove any excess moisture.

2.2.3 Needle valve—To adjust flow rate.

2.2.4 Pump—Leak-free, diaphragm type, or equivalent, to pull gas.

2.2.5 Rate meter—To measure a flow range from 0 to 0.035 cfm.

2.2.6 Flexible bag—Tedlar,¹ or equivalent, with a capacity of 2 to 3 cu. ft. Leak test the bag in the laboratory before using.

2.2.7 Pitot tube—Type S, or equivalent, attached to the probe so that the sampling flow rate can be regulated proportional to the stack gas velocity when velocity is varying with time or a sample traverse is conducted.

2.3 Analysis.

2.3.1 Orsat analyzer, or equivalent.

¹ Trade name.

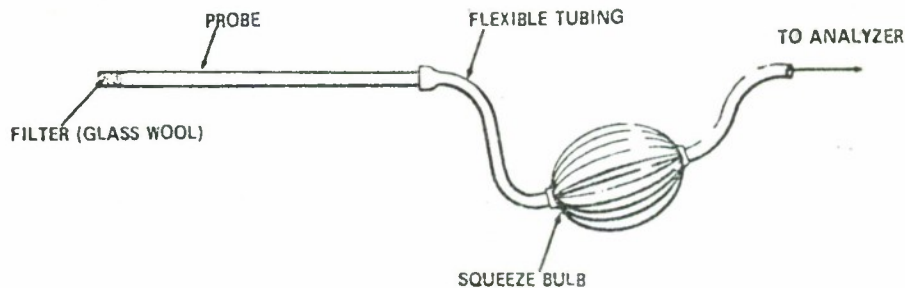


Figure 3-1. Grab-sampling train.

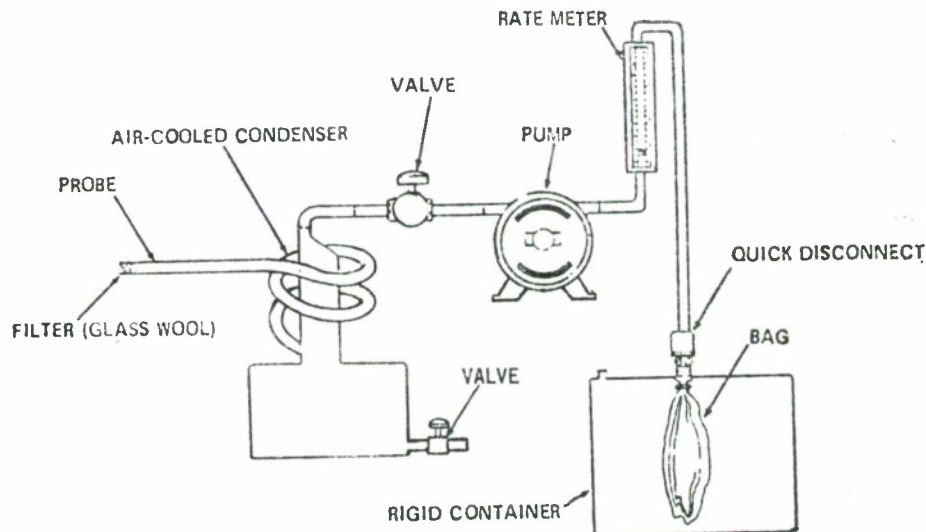


Figure 3-2. Integrated gas - sampling train.

3. Procedure.

3.1 Grab sampling.

3.1.1 Set up the equipment as shown in Figure 3-1, making sure all connections are leak-free. Place the probe in the stack at a sampling point and purge the sampling line.

3.1.2 Draw sample into the analyzer.

3.2 Integrated sampling.

3.2.1 Evacuate the flexible bag. Set up the equipment as shown in Figure 3-2 with the bag disconnected. Place the probe in the stack and purge the sampling line. Connect the bag, making sure that all connections are tight and that there are no leaks.

3.2.2 Sample at a rate proportional to the stack velocity.

3.3 Analysis.

3.3.1 Determine the CO_2 , O_2 , and CO concentrations as soon as possible. Make as many passes as are necessary to give constant readings. If more than ten passes are necessary, replace the absorbing solution.

3.3.2 For grab sampling, repeat the sampling and analysis until three consecutive samples vary no more than 0.5 percent by volume for each component being analyzed.

3.3.3 For integrated sampling, repeat the analysis of the sample until three consecutive analyses vary no more than 0.2 percent by volume for each component being analyzed.

4. Calculations.

4.1 Carbon dioxide. Average the three consecutive runs and report the result to the nearest 0.1% CO_2 .

4.2 Excess air. Use Equation 3-1 to calculate excess air, and average the runs. Report the result to the nearest 0.1% excess air.

% EA =

$$\frac{(\% \text{O}_2) - 0.5(\% \text{CO})}{0.264(\% \text{N}_2) - (\% \text{O}_2) + 0.5(\% \text{CO})} \times 100$$

equation 3-1

where:

% EA = Percent excess air.

% O_2 = Percent oxygen by volume, dry basis.

% N_2 = Percent nitrogen by volume, dry basis.

% CO = Percent carbon monoxide by volume, dry basis.

0.264 = Ratio of oxygen to nitrogen in air by volume.

4.3 Dry molecular weight. Use Equation 3-2 to calculate dry molecular weight and average the runs. Report the result to the nearest tenth.

$$M_d = 0.44(\% \text{CO}_2) + 0.32(\% \text{O}_2) + 0.28(\% \text{N}_2 + \% \text{CO})$$

equation 3-2

where:

M_d = Dry molecular weight, lb./lb.-mole.

% CO_2 = Percent carbon dioxide by volume, dry basis.

% O_2 = Percent oxygen by volume, dry basis.

% N_2 = Percent nitrogen by volume, dry basis.

0.44 = Molecular weight of carbon dioxide divided by 100.

0.32 = Molecular weight of oxygen divided by 100.

0.28 = Molecular weight of nitrogen and CO divided by 100.

5. References.

Altshuller, A. P., et al., Storage of Gases and Vapors in Plastic Bags, *Int. J. Air & Water Pollution*, 6:75-81, 1963.

Conner, William D., and J. S. Nader, Air Sampling with Plastic Bags, *Journal of the American Industrial Hygiene Association*, 25:291-297, May-June 1964.

Devorkin, Howard, et al., Air Pollution Source Testing Manual, Air Pollution Control District, Los Angeles, Calif., November 1963.

METHOD 4—DETERMINATION OF MOISTURE IN STACK GASES

1. Principle and applicability.

1.1 Principle. Moisture is removed from the gas stream, condensed, and determined volumetrically.

1.2 Applicability. This method is applicable for the determination of moisture in stack gas only when specified by test procedures for determining compliance with New Source Performance Standards. This method does not apply when liquid droplets are present in the gas stream¹ and the moisture is subsequently used in the determination of stack gas molecular weight.

Other methods such as drying tubes, wet bulb-dry bulb techniques, and volumetric condensation techniques may be used.

2. Apparatus.

2.1 Probe—Stainless steel or Pyrex[®] glass sufficiently heated to prevent condensation and equipped with a filter to remove particulate matter.

2.2 Impingers—Two midget impingers each with 30 ml. capacity, or equivalent.

2.3 Ice bath container—To condense moisture in impingers.

2.4 Silica gel tube (optional)—To protect pump and dry gas meter.

2.5 Needle valve—To regulate gas flow rate.

2.6 Pump—Leak-free, diaphragm type, or equivalent, to pull gas through train.

2.7 Dry gas meter—To measure to within 1% of the total sample volume.

2.8 Rotameter—To measure a flow range from 0 to 0.1 c.f.m.

2.9 Graduated cylinder—25 ml.

2.10 Barometer—Sufficient to read to within 0.1 inch Hg.

2.11 Pitot tube—Type B, or equivalent attached to probe so that the sampling flow

¹ If liquid droplets are present in the gas stream, assume the stream to be saturated, determine the average stack gas temperature by traversing according to Method 1, and use a psychrometric chart to obtain an approximation of the moisture percentage.

[®] Trade name.

rate can be regulated proportional to the stack gas velocity when velocity is varying with time or a sample traverse is conducted.

3. Procedure.

3.1 Place exactly 5 ml. distilled water in each impinger. Assemble the apparatus without the probe as shown in Figure 4-1. Leak check by plugging the inlet to the first impinger and drawing a vacuum. Insure that flow through the dry gas meter is less than 1% of the sampling rate.

3.2 Connect the probe and sample at a

constant rate of 0.075 c.f.m. or at a rate proportional to the stack gas velocity. Continue sampling until the dry gas meter registers 1 cubic foot or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-2.

3.3 After collecting the sample, measure the volume increase to the nearest 0.5 ml.

4. Calculations.

4.1 Volume of water vapor collected.

$$V_{wv} = \frac{(V_f - V_i) \rho_{H_2O} R T_{std}}{P_{std} M_{H_2O}} = 0.0474 \frac{\text{ft.}^3}{\text{ml.}} (V_f - V_i) \quad \text{equation 4-1}$$

where:

V_{wv} = Volume of water vapor collected (standard conditions), cu. ft.

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

R = Ideal gas constant, 21.83 inches Hg—cu. ft./lb. mole—°R.

ρ_{H_2O} = Density of water, 1 g./ml.

T_{std} = Absolute temperature at standard conditions, 530° R.

P_{std} = Absolute pressure at standard conditions, 29.92 inches Hg.

M_{H_2O} = Molecular weight of water, 18 lb./lb.-mole.

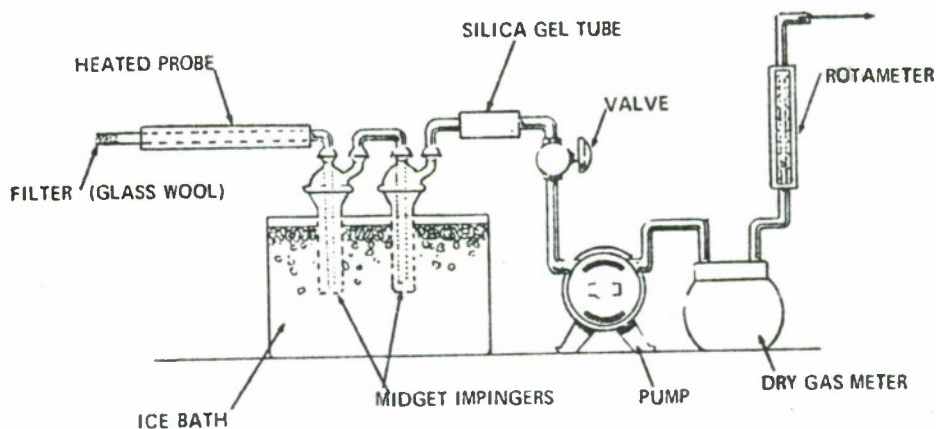


Figure 4-1. Moisture-sampling train.

LOCATION _____ COMMENTS _____
 TEST _____
 DATE _____
 OPERATOR _____
 BAROMETRIC PRESSURE _____

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), ft ³	ROTAMETER SETTING ft ³ /min	METER TEMPERATURE, °F

Figure 4-2. Field moisture determination.

4.2 Gas volume.

$$V_{m_s} = V_m \left(\frac{P_m}{P_{std}} \right) \left(\frac{T_{std}}{T_m} \right) =$$

$$17.71 \frac{^\circ R}{\text{in. Hg}} \left(\frac{V_m P_m}{T_m} \right) \quad \text{equation 4-2}$$

where:

 V_{m_s} = Dry gas volume through meter at standard conditions, cu. ft. V_m = Dry gas volume measured by meter, cu. ft. P_m = Barometric pressure at the dry gas meter, inches Hg. P_{std} = Pressure at standard conditions, 29.92 inches Hg. T_{std} = Absolute temperature at standard conditions, 530° R. T_m = Absolute temperature at meter (°F + 460), °R.

4.3 Moisture content.

$$B_{w_s} = \frac{V_{w_s}}{V_{w_s} + V_{m_s}} + B_{w_m} = \frac{V_{w_s}}{V_{w_s} + V_{m_s}} + (0.025)$$

equation 4-3

where:

 B_{w_s} = Proportion by volume of water vapor in the gas stream, dimensionless. V_{w_s} = Volume of water vapor collected (standard conditions), cu. ft. V_{m_s} = Dry gas volume through meter (standard conditions), cu. ft. B_{w_m} = Approximate volumetric proportion of water vapor in the gas stream leaving the impingers, 0.025.

5. References.

Air Pollution Engineering Manual, Danielson, J. A. (ed.), U.S. DHEW, PHS, National Center for Air Pollution Control, Cincinnati, Ohio, PHS Publication No. 999-AP-40, 1967.

Devorkin, Howard, et al., Air Pollution Source Testing Manual, Air Pollution Control District, Los Angeles, Calif., November 1963.

Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases, Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif., Bulletin WP-50, 1968.

METHOD 5—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and its weight is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Apparatus.

2.1 Sampling train. The design specifications of the particulate sampling train used by EPA (Figure 5-1) are described in APTD-0581. Commercial models of this train are available.

2.1.1 Nozzle—Stainless steel (316) with sharp, tapered leading edge.

2.1.2 Probe—Pyrex¹ glass with a heating system capable of maintaining a minimum gas temperature of 250° F. at the exit end during sampling to prevent condensation from occurring. When length limitations (greater than about 8 ft.) are encountered at temperatures less than 600° F., Incoloy 825¹, or equivalent, may be used. Probes for sampling gas streams at temperatures in excess of 600° F. must have been approved by the Administrator.

2.1.3 Pitot tube—Type S, or equivalent, attached to probe to monitor stack gas velocity.

¹ Trade name.

2.1.4 Filter Holder—Pyrex¹ glass with heating system capable of maintaining minimum temperature of 225° F.

2.1.5 Impingers / Condenser—Four impingers connected in series with glass ball joint fittings. The first, third, and fourth impingers are of the Greenburg-Smith design, modified by replacing the tip with a 1/2-inch ID glass tube extending to one-half inch from the bottom of the flask. The second impinger is of the Greenburg-Smith design with the standard tip. A condenser may be used in place of the impingers provided that the moisture content of the stack gas can still be determined.

2.1.6 Metering system—Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 5° F., dry gas meter with 2% accuracy, and related equipment, or equivalent, as required to maintain an isokinetic sampling rate and to determine sample volume.

2.1.7 Barometer—To measure atmospheric pressure to ±0.1 inches Hg.

2.2 Sample recovery.

2.2.1 Probe brush—At least as long as probe.

2.2.2 Glass wash bottles—Two.

2.2.3 Glass sample storage containers.

2.2.4 Graduated cylinder—250 ml.

2.3 Analysis.

2.3.1 Glass weighing dishes.

2.3.2 Desiccator.

2.3.3 Analytical balance—To measure to ±0.1 mg.

2.3.4 Trip balance—300 g. capacity, to measure to ±0.05 g.

3. Reagents.

3.1 Sampling.

3.1.1 Filters—Glass fiber, MSA 1106 BH¹, or equivalent, numbered for identification and preweighed.

3.1.2 Silica gel—Indicating type, 6-16 mesh, dried at 175° C. (350° F.) for 2 hours.

3.1.3 Water.

3.1.4 Crushed ice.

3.2 Sample recovery.

3.2.1 Acetone—Reagent grade.

3.3 Analysis.

3.3.1 Water.

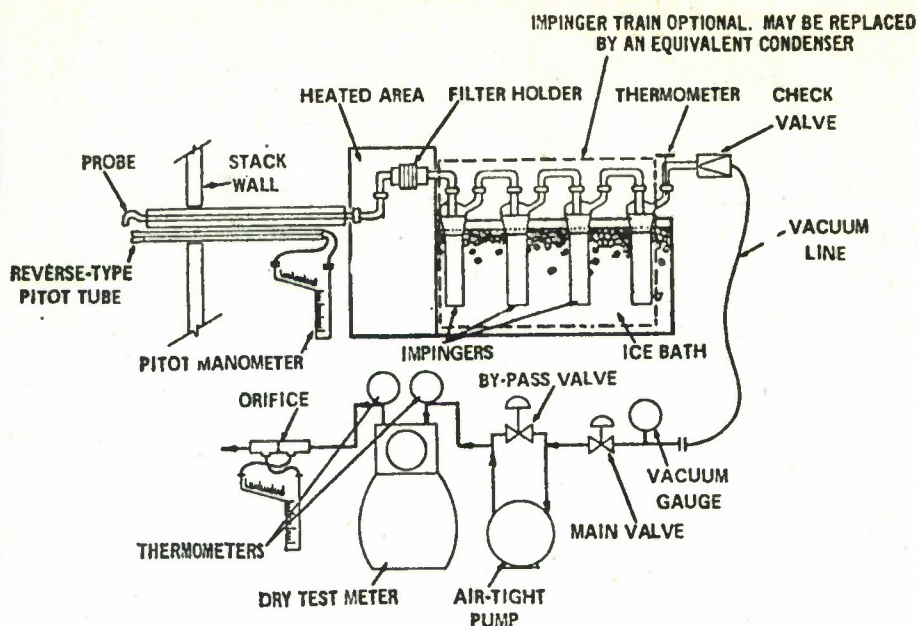


Figure 5-1. Particulate-sampling train.

3.3.2 Desiccant—Drierite,¹ indicating.

4. Procedure.

4.1 Sampling

4.1.1 After selecting the sampling site and the minimum number of sampling points, determine the stack pressure, temperature, moisture, and range of velocity head.

4.1.2 Preparation of collection train. Weigh to the nearest gram approximately 200 g. of silica gel. Label a filter of proper diameter, desiccate² for at least 24 hours and weigh to the nearest 0.5 mg. in a room where the relative humidity is less than 50%. Place 100 ml. of water in each of the first two impingers, leave the third impinger empty,

and place approximately 200 g. of preweighed silica gel in the fourth impinger. Set up the train without the probe as in Figure 5-1. Leak check the sampling train at the sampling site by plugging up the inlet to the filter holder and pulling a 15 in. Hg vacuum. A leakage rate not in excess of 0.02 c.f.m. at a vacuum of 15 in. Hg is acceptable. Attach the probe and adjust the heater to provide a gas temperature of about 250° F. at the probe outlet. Turn on the filter heating system. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the gases leaving the last impinger as low as possible and preferably at 70° F., or less. Temperatures above 70° F. may result in damage to the dry gas meter from either moisture condensation or excessive heat.

¹ Trade name.

² Dry using Drierite¹ at 70° F. \pm 10° F.

piling time must be the same for each point. Maintain isokinetic sampling throughout the sampling period. Nomographs are available which aid in the rapid adjustment of the sampling rate without other computations. APID-0578 details the procedure for using these nomographs. Turn off the pump at the conclusion of each run and record the final readings. Remove the probe and nozzle from the stack and handle in accordance with the sample recovery process described in section 4.2.

[illegible]

Figure 5-2. Particulate field data.

Container No. 3. Transfer the silica gel from the fourth impinger to the original container and seal. Use a rubber policeman as an aid in removing silica gel from the impinger.

Container No. 1. Remove the filter from its holder, place in this container, and seal.

4.3 Analysis. Record the data required on the example sheet shown in Figure 5-3. Handle each sample container as follows:

Container No. 1. Transfer the filter and any loose particulate matter from the sample container to a tared glass weighing dish, desiccate, and dry to a constant weight. Report results to the nearest 0.5 mg.

Container No. 2. Transfer the acetone washings to a tared beaker and evaporate to dryness at ambient temperature and pressure. Desiccate and dry to a constant weight. Report results to the nearest 0.5 mg.

Container No. 3. Weigh the spent silica gel and report to the nearest gram.

5. Calibration.

Use methods and equipment which have been approved by the Administrator to calibrate the orifice meter, pilot tube, dry gas meter, and probe heater. Recalibrate after each test series.

6. Calculations.

6.1 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-2).

6.2 Dry gas volume. Correct the sample volume measured by the dry gas meter to standard conditions (70° F., 29.92 inches Hg) by using Equation 5-1.

$$V_{m, std} = V_m \left(\frac{T_{std}}{T_m} \right) \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}} \right) =$$

$$\left(17.71 \frac{^{\circ}R}{in. Hg} \right) V_m \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m} \right)$$

equation 5-1

where:

$V_{m, std}$ —Volume of gas sample through the dry gas meter (standard conditions), cu. ft.

V_m —Volume of gas sample through the dry gas meter (meter conditions), cu. ft.

T_{std} —Absolute temperature at standard conditions, 530° R.

T_m —Average dry gas meter temperature, °R.

P_{bar} —Barometric pressure at the orifice meter, inches Hg.

ΔH —Average pressure drop across the orifice meter, inches H₂O.

13.6—Specific gravity of mercury.

P_{std} —Absolute pressure at standard conditions, 29.92 inches Hg.

6.3 Volume of water vapor.

$$V_{w, std} = V_{l, std} \frac{\rho_{H_2O}}{M_{H_2O}} \frac{RT_{std}}{P_{std}} \frac{lb.}{454 gm.}$$

$$= 0.0474 \frac{cu. ft.}{ml.} V_{l, std}$$

equation 5-2

where:

$V_{w, std}$ —Volume of water vapor in the gas sample (standard conditions), cu. ft.

$V_{l, std}$ —Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.

ρ_{H_2O} —Density of water, 1 g./ml.

M_{H_2O} —Molecular weight of water, 18 lb./lb.-mole.

R —Ideal gas constant, 21.63 inches Hg—cu. ft./lb.-mole-°R.

T_{std} —Absolute temperature at standard conditions, 530° R.

P_{std} —Absolute pressure at standard conditions, 29.92 inches Hg.

6.4 Moisture content.

$$B_{w, std} = \frac{V_{w, std}}{V_{m, std} + V_{w, std}}$$

equation 5-3

where:

$B_{w, std}$ —Proportion by volume of water vapor in the gas stream, dimensionless.

$V_{w, std}$ —Volume of water in the gas sample (standard conditions), cu. ft.

$V_{m, std}$ —Volume of gas sample through the dry gas meter (standard conditions), cu. ft.

6.5 Total particulate weight. Determine the total particulate catch from the sum of the weights on the analysis data sheet (Figure 5-3).

6.6 Concentration.

6.6.1 Concentration in gr./s.c.f.

$$c' = \left(0.0154 \frac{gr.}{mg.} \right) \left(\frac{M_p}{V_{m, std}} \right)$$

equation 5-4

where:

c' —Concentration of particulate matter in stack gas, gr./s.c.f., dry basis.

M_p —Total amount of particulate matter collected, mg.

$V_{m, std}$ —Volume of gas sample through dry gas meter (standard conditions), cu. ft.

6.6.2 Concentration in lb./cu. ft.

$$c_s = \frac{\left(\frac{1}{453,600} \frac{\text{lb.}}{\text{mg.}}\right) M_s}{V_{s,d}} = 2.205 \times 10^{-6} \frac{M_s}{V_{s,d}} \quad \text{equation 5-5}$$

where:

c_s = Concentration of particulate matter in stack gas, lb./s.c.f., dry basis.
 453,600 = M_g /lb.

M_s = Total amount of particulate matter collected
 mg.
 $V_{s,d}$ = Volume of gas sample through dry gas meter
 (standard conditions), cu. ft.

6.7 Isokinetic variation.

$$I = T_s \left[\left(\frac{0.00267 \text{ in. Hg-cu. ft.}}{\text{ml-}^\circ\text{R}} \right) V_1 + \frac{V_m}{T_m} \left(P_{bs} + \frac{H}{13.6} \right) \right] \left(1.687 \frac{\text{min.}}{\text{sec.}} \right) \quad \text{equation 5-6}$$

$\theta V_s P_s A_s$

where:

I = Percent of isokinetic sampling.
 V_1 = Total volume of liquid collected in impingers and silica gel (See Fig. 5-3), ml.
 ρ_{H_2O} = Density of water, 1 g./ml.
 R = Ideal gas constant, 21.83 inches Hg-cu. ft./lb.-mole- $^\circ\text{R}$.
 M_{H_2O} = Molecular weight of water, 18 lb./lb.-mole.
 V_m = Volume of gas sample through the dry gas meter (meter conditions), cu. ft.
 T_m = Absolute average dry gas meter temperature (see Figure 5-2), $^\circ\text{R}$.
 P_{bs} = Barometric pressure at sampling site, inches Hg.
 ΔH = Average pressure drop across the orifice (see Fig. 5-2), inches H_2O .
 T_s = Absolute average stack gas temperature (see Fig. 5-2), $^\circ\text{R}$.
 θ = Total sampling time, min.
 V_s = Stack gas velocity calculated by Method 2, Equation 2-2, ft./sec.
 P_s = Absolute stack gas pressure, inches Hg.
 A_s = Cross-sectional area of nozzle, sq. ft.

6.8 Acceptable results. The following range sets the limit on acceptable isokinetic sampling results:

If $90\% \leq I \leq 110\%$, the results are acceptable, otherwise, reject the results and repeat the test.

7. Reference.

Addendum to Specifications for Incinerator Testing at Federal Facilities, PHS, NOAPO, Dec. 4, 1967.

Martin, Robert M., Construction Details of Isokinetic Source Sampling Equipment, Environmental Protection Agency, APTD-0581.

Rom, Jerome J., Maintenance, Calibration, and Operation of Isokinetic Source Sampling Equipment, Environmental Protection Agency, APTD-0576.

Smith, W. S., R. T. Shigehara, and W. F. Todd, A Method of Interpreting Stack Sampling Data, Paper presented at the 63d Annual Meeting of the Air Pollution Control Association, St. Louis, Mo., June 14-19, 1970.

Smith, W. S., et al., Stack Gas Sampling Improved and Simplified with New Equipment, APCA paper No. 67-119, 1967.

Specifications for Incinerator Testing at Federal Facilities, PHS, NCAPO, 1967.

METHOD 6—DETERMINATION OF SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. A gas sample is extracted from the sampling point in the stack. The acid mist, including sulfur trioxide, is separated from the sulfur dioxide. The sulfur dioxide fraction is measured by the barium-thorin titration method.

1.2 Applicability. This method is applicable for the determination of sulfur dioxide emissions from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Apparatus.

2.1 Sampling. See Figure 6-1.

2.1.1 Probe—Pyrex¹ glass, approximately 5 to 6 mm. ID, with a heating system to prevent condensation and a filtering medium to remove particulate matter including sulfuric acid mist.

2.1.2 Midget bubbler—One, with glass wool packed in top to prevent sulfuric acid mist carryover.

2.1.3 Glass wool.

2.1.4 Midget impingers—Three.

2.1.5 Drying tube—Packed with 6 to 16 mesh indicating-type silica gel, or equivalent, to dry the sample.

2.1.6 Valve—Needle valve, or equivalent, to adjust flow rate.

2.1.7 Pump—Leak-free, vacuum type.

2.1.8 Rate meter—Rotameter or equivalent, to measure a 0-10 s.c.f.h. flow range.

2.1.9 Dry gas meter—Sufficiently accurate to measure the sample volume within 1%.

2.1.10 Pitot tube—Type S, or equivalent necessary only if a sample traverse is required, or if stack gas velocity varies with time.

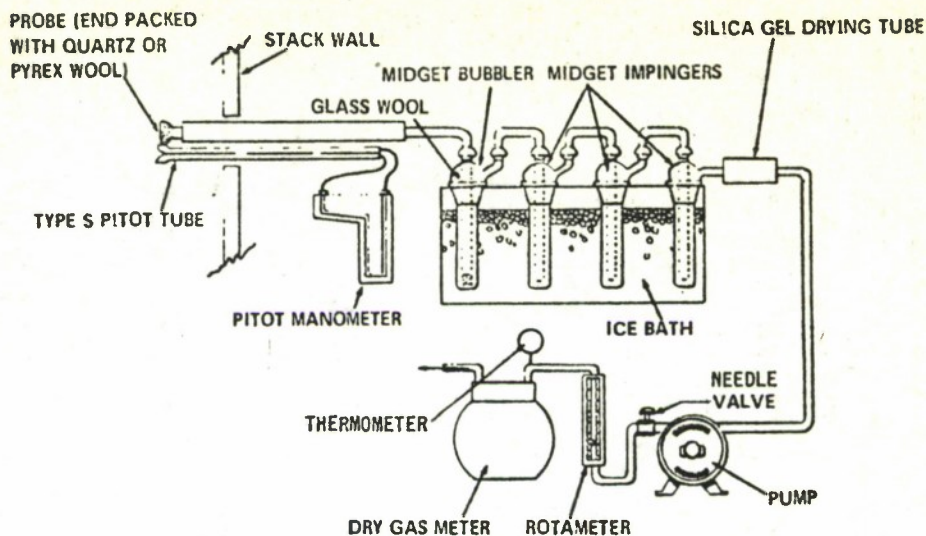
2.2 Sample recovery.

2.2.1 Glass wash bottles—Two.

2.2.2 Polyethylene storage bottles—To store impinger samples.

2.3 Analysis.

¹ Trade names

Figure 6-1. SO₂ sampling train.

2.3.1 Pipettes—Transfer type, 5 ml. and 10 ml. sizes (0.1 ml. divisions) and 25 ml. size (0.2 ml. divisions).

2.3.2 Volumetric flasks—50 ml., 100 ml., and 1,000 ml.

2.3.3 Burettes—5 ml. and 50 ml.

2.3.4 Erlenmeyer flask—125 ml.

3. Reagents.

3.1 Sampling.

3.1.1 Water—Deionized, distilled.

3.1.2 Isopropanol, 80%—Mix 80 ml. of isopropanol with 20 ml. of distilled water.

3.1.3 Hydrogen peroxide, 3%—dilute 100 ml. of 30% hydrogen peroxide to 1 liter with distilled water. Prepare fresh daily.

3.2 Sample recovery.

3.2.1 Water—Deionized, distilled.

3.2.2 Isopropanol, 80%.

3.3 Analysis.

3.3.1 Water—Deionized, distilled.

3.3.2 Isopropanol.

3.3.3 Thorin Indicator—1-(o-arsenophenylazo)-2-naphthol-3,6-disulfonic acid, disodium salt (or equivalent). Dissolve 0.20 g. in 100 ml. distilled water.

3.3.4 Barium perchlorate (0.01 N)—Dissolve 1.95 g. of barium perchlorate [$\text{Ba}(\text{ClO}_4)_2 \cdot 3\text{H}_2\text{O}$] in 200 ml. distilled water and dilute to 1 liter with isopropanol. Standardize with sulfuric acid. Barium chloride may be used.

3.3.5 Sulfuric acid standard (0.01 N)—Purchase or standardize to ± 0.0002 N against 0.01N NaOH which has previously been standardized against potassium acid phthalate (primary standard grade).

4. Procedure.

4.1 Sampling.

4.1.1 Preparation of collection train. Pour 15 ml. of 80% isopropanol into the midget bubbler and 15 ml. of 3% hydrogen peroxide into each of the first two midget impingers. Leave the final midget impinger dry. Assemble the train as shown in Figure 6-1. Leak check the sampling train at the sampling site by plugging the probe inlet and pulling a 10 inches Hg vacuum. A leakage rate not in excess of 1% of the sampling rate is acceptable. Carefully release the probe inlet plug and turn off the pump. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the gases leaving the last impinger at 70° F. or less.

4.1.2 Sample collection. Adjust the sample flow rate proportional to the stack gas velocity. Take readings at least every five minutes and when significant changes in stack conditions necessitate additional adjustments in flow rate. To begin sampling, position the tip of the probe at the first sampling point and start the pump. Sample proportionally throughout the run. At the conclusion of each run, turn off the pump and record the final readings. Remove the probe from the stack and disconnect it from the train. Drain the ice bath and purge the remaining part of the train by drawing clean ambient air through the system for 15 minutes.

4.2 Sample recovery. Disconnect the impingers after purging. Discard the contents of the midget bubbler. Pour the contents of the midget impingers into a polyethylene shipment bottle. Rinse the three midget impingers and the connecting tubes with dis-

tilled water and add these washings to the same storage container.

4.3 Sample analysis. Transfer the contents of the storage container to a 50 ml. volumetric flask. Dilute to the mark with deionized, distilled water. Pipette a 10 ml. aliquot of this solution into a 125 ml. Erlenmeyer flask. Add 40 ml. of isopropanol and two to four drops of thiorin indicator. Titrate to a pink endpoint using 0.01 *N* barium perchlorate. Run a blank with each series of samples.

5. Calibration.

5.1 Use standard methods and equipment which have been approved by the Administrator to calibrate the rotameter, pitot tube, dry gas meter, and probe heater.

5.2 Standardize the barium perchlorate against 25 ml. of standard sulfuric acid containing 100 ml. of isopropanol.

6. Calculations.

6.1 Dry gas volume. Correct the sample volume measured by the dry gas meter to

standard conditions (70° F. and 29.92 inches Hg) by using equation 6-1.

$$V_{m, std} = V_m \left(\frac{T_{std}}{T_m} \right) \left(\frac{P_{bar}}{P_{std}} \right) = 17.71 \frac{^{\circ}R}{\text{in. Hg}} \left(\frac{V_m P_{bar}}{T_m} \right) \quad \text{equation 6-1}$$

where:

$V_{m, std}$ = Volume of gas sample through the dry gas meter (standard conditions), cu. ft.

V_m = Volume of gas sample through the dry gas meter (meter conditions), cu. ft.

T_{std} = Absolute temperature at standard conditions, 530° R.

T_m = Average dry gas meter temperature, °R.

P_{bar} = Barometric pressure at the orifice meter, inches Hg.

P_{std} = Absolute pressure at standard conditions, 29.92 inches Hg.

6.2 Sulfur dioxide concentration.

$$C_{SO_2} = \left(7.05 \times 10^{-3} \frac{\text{lb.-l.}}{\text{g.-ml.}} \right) \frac{(V_t - V_{tb}) N \left(\frac{V_{soln}}{V_s} \right)}{V_{m, std}} \quad \text{equation 6-2}$$

where:

C_{SO_2} = Concentration of sulfur dioxide at standard conditions, dry basis, lb./cu. ft.

7.05×10^{-3} = Conversion factor, including the number of grams per gram equivalent of sulfur dioxide (32 g./g.-eq.), 453.6 g./lb., and 1,000 ml./l., lb.-l./g.-ml.

V_t = Volume of barium perchlorate titrant used for the sample, ml.

V_{tb} = Volume of barium perchlorate titrant used for the blank, ml.

N = Normality of barium perchlorate titrant, g.-eq./l.

V_{soln} = Total solution volume of sulfur dioxide, 50 ml.

V_s = Volume of sample aliquot titrated, ml.

$V_{m, std}$ = Volume of gas sample through the dry gas meter (standard conditions), cu. ft., see Equation 6-1.

7. References.

Atmospheric Emissions from Sulfuric Acid Manufacturing Processes, U.S. DHEW, PHS, Division of Air Pollution, Public Health Service Publication No. 099-AP-13, Cincinnati, Ohio, 1965.

Corbett, P. F., The Determination of SO_2 and SO_3 in Flue Gases, Journal of the Institute of Fuel, 24:237-243, 1961.

Matty, R. E. and E. K. Diehl, Measuring Flue-Gas SO_2 and SO_3 , Power 101:94-97, November, 1957.

Patton, W. F. and J. A. Brink, Jr., New Equipment and Techniques for Sampling Chemical Process Gases, J. Air Pollution Control Association, 13, 162 (1963).

METHOD 7—DETERMINATION OF NITROGEN OXIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. A grab sample is collected in an evacuated flask containing a dilute sulfuric acid-hydrogen peroxide absorbing solution, and the nitrogen oxides, except nitrous oxide, are measured colorimetrically using the phenoldisulfonic acid (PDS) procedure.

1.2 Applicability. This method is applicable for the measurement of nitrogen oxides from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Apparatus.

2.1 Sampling. See Figure 7-1.

2.1.1 Probe—Pyrex¹ glass, heated, with filter to remove particulate matter. Heating is unnecessary if the probe remains dry during the purging period.

2.1.2 Collection flask—Two-liter, Pyrex,¹ round bottom with short neck and 24/40 standard taper opening, protected against implosion or breakage.

2.1.3 Flask valve—T-bore stopcock connected to a 24/40 standard taper joint.

2.1.4 Temperature gauge—Dial-type thermometer, or equivalent, capable of measuring 2° F. intervals from 25° to 125° F.

2.1.5 Vacuum line—Tubing capable of withstanding a vacuum of 3 inches Hg absolute pressure, with "T" connection and T-bore stopcock, or equivalent.

2.1.6 Pressure gauge—U-tube manometer, 36 inches, with 0.1-inch divisions, or equivalent.

¹ Trade name.

2.1.7 Pump—Capable of producing a vacuum of 3 inches Hg absolute pressure.

2.1.8 Squeeze bulb—One way.

2.2 Sample recovery.

2.2.1 Pipette or dropper.

2.2.2 Glass storage containers—Cushioned for shipping.

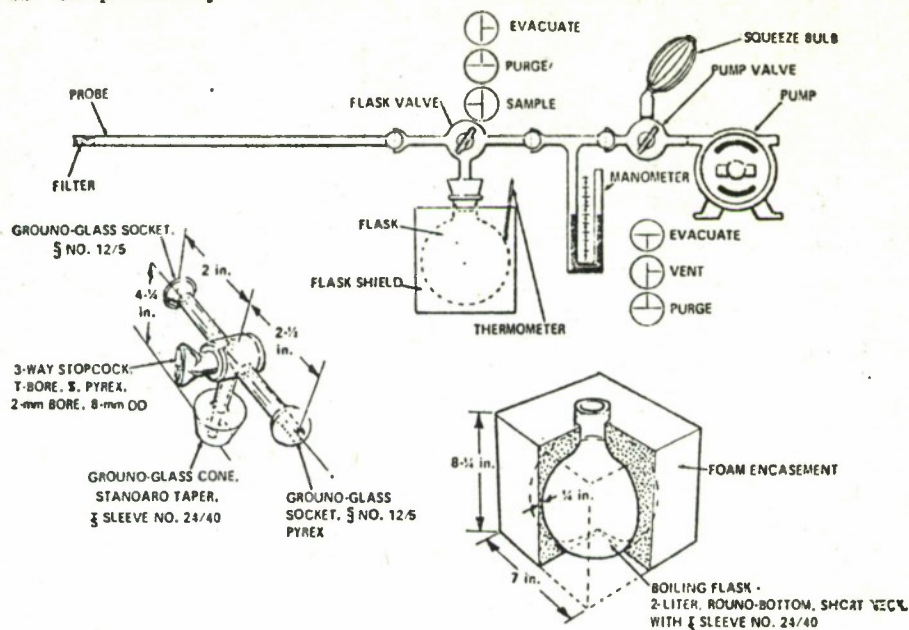


Figure 7-1. Sampling train, flask valve, and flask.

2.2.3. Glass wash bottle.

2.3 Analysis.

2.3.1 Steam bath.

2.3.2 Beakers or casseroles—250 ml., one for each sample and standard (blank).

2.3.3 Volumetric pipettes—1, 2, and 10 ml.

2.3.4 Transfer pipette—10 ml. with 0.1 ml. divisions.

2.3.5 Volumetric flask—100 ml., one for each sample, and 1,000 ml. for the standard (blank).

2.3.6 Spectrophotometer—To measure absorbance at 420 nm.

2.3.7 Graduated cylinder—100 ml. with 1.0 ml. divisions.

2.3.8 Analytical balance—To measure to 0.1 mg.

3. Reagents.

3.1 Sampling.

3.1.1 Absorbing solution—Add 2.8 ml. of concentrated H_2SO_4 to 1 liter of distilled water. Mix well and add 8 ml. of 3 percent hydrogen peroxide. Prepare a fresh solution weekly and do not expose to extreme heat or direct sunlight.

3.2 Sample recovery.

3.2.1 Sodium hydroxide (1N)—Dissolve 40 g. NaOH in distilled water and dilute to 1 liter.

3.2.2 Red litmus paper.

3.2.3 Water—Deionized, distilled.

3.3 Analysis.

3.3.1 Fuming sulfuric acid—15 to 18% by weight free sulfur trioxide.

3.3.2 Phenol—White solid reagent grade.

3.3.3 Sulfuric acid—Concentrated reagent grade.

3.3.4 Standard solution—Dissolve 0.5496 g. potassium nitrate (KNO_3) in distilled water and dilute to 1 liter. For the working standard solution, dilute 10 ml. of the resulting solution to 100 ml. with distilled water. One ml. of the working standard solution is equivalent to 25 μ g. nitrogen dioxide.

3.3.5 Water—Deionized, distilled.

3.3.6 Phenoldisulfonic acid solution—Dissolve 25 g. of pure white phenol in 150 ml. concentrated sulfuric acid on a steam bath. Cool, add 75 ml. fuming sulfuric acid, and heat at 100° C. for 2 hours. Store in a dark, stoppered bottle.

4. Procedure.

4.1 Sampling.

4.1.1 Pipette 25 ml. of absorbing solution into a sample flask. Insert the flask valve stopper into the flask with the valve in the "purge" position. Assemble the sampling train as shown in Figure 7-1 and place the probe at the sampling point. Turn the flask valve and the pump valve to their "evacuate" positions. Evacuate the flask to at least 3 inches Hg absolute pressure. Turn the pump

valve to its "vent" position and turn off the pump. Check the manometer for any fluctuation in the mercury level. If there is a visible change over the span of one minute, check for leaks. Record the initial volume, temperature, and barometric pressure. Turn the flask valve to its "purge" position, and then do the same with the pump valve. Purge the probe and the vacuum tube using the squeeze bulb. If condensation occurs in the probe and flask valve area, heat the probe and purge until the condensation disappears. Then turn the pump valve to its "vent" position. Turn the flask valve to its "sample" position and allow sample to enter the flask for about 15 seconds. After collecting the sample, turn the flask valve to its "purge" position and disconnect the flask from the sampling train. Shake the flask for 5 minutes.

4.2 Sample recovery.

4.2.1 Let the flask set for a minimum of 16 hours and then shake the contents for 2 minutes. Connect the flask to a mercury filled U-tube manometer, open the valve from the flask to the manometer, and record the flask pressure and temperature along with the barometric pressure. Transfer the flask contents to a container for shipment or to a 250 ml. beaker for analysis. Rinse the flask with two portions of distilled water (approximately 10 ml.) and add rinse water to the sample. For a blank use 25 ml. of absorbing solution and the same volume of distilled water as used in rinsing the flask. Prior to shipping or analysis, add sodium hydroxide (1N) dropwise into both the sample and the blank until alkaline to litmus paper (about 25 to 35 drops in each).

4.3 Analysis.

4.3.1 If the sample has been shipped in a container, transfer the contents to a 250 ml. beaker using a small amount of distilled

$$V_{..} = \frac{T_{std}(V_f - V_a)}{P_{std}} \left(\frac{P_f - P_i}{T_f - T_i} \right) = \left(17.71 \frac{^{\circ}\text{R}}{\text{in. Hg.}} \right) (V_f - 25 \text{ ml.}) \left(\frac{P_f - P_i}{T_f - T_i} \right) \quad \text{Equation 7-1}$$

where:

$V_{..}$ —Sample volume at standard conditions (dry basis), ml.

T_{std} —Absolute temperature at standard conditions, 530° R.

P_{std} —Pressure at standard conditions, 29.92 inches Hg.

V_f —Volume of flask and valve, ml.

V_a —Volume of absorbing solution, 25 ml.

water. Evaporate the solution to dryness on a steam bath and then cool. Add 2 ml. phenol-disulfonic acid solution to the dried residue and triturate thoroughly with a glass rod. Make sure the solution contacts all the residue. Add 1 ml. distilled water and four drops of concentrated sulfuric acid. Heat the solution on a steam bath for 3 minutes with occasional stirring. Cool, add 20 ml. distilled water, mix well by stirring, and add concentrated ammonium hydroxide dropwise with constant stirring until alkaline to litmus paper. Transfer the solution to a 100 ml. volumetric flask and wash the beaker three times with 4 to 5 ml. portions of distilled water. Dilute to the mark and mix thoroughly. If the sample contains solids, transfer a portion of the solution to a clean, dry centrifuge tube, and centrifuge, or filter a portion of the solution. Measure the absorbance of each sample at 420 nm. using the blank solution as a zero. Dilute the sample and the blank with a suitable amount of distilled water if absorbance falls outside the range of calibration.

5. Calibration.

5.1 Flask volume. Assemble the flask and flask valve and fill with water to the stopcock. Measure the volume of water to ± 10 ml. Number and record the volume on the flask.

5.2 Spectrophotometer. Add 0.0 to 16.0 ml. of standard solution to a series of beakers. To each beaker add 25 ml. of absorbing solution and add sodium hydroxide (1N) dropwise until alkaline to litmus paper (about 25 to 35 drops). Follow the analysis procedure of section 4.3 to collect enough data to draw a calibration curve of concentration in $\mu\text{g. NO}_x$ per sample versus absorbance.

6. Calculations.

6.1 Sample volume.

P_f —Final absolute pressure of flask, inches Hg.

P_i —Initial absolute pressure of flask, inches Hg.

T_f —Final absolute temperature of flask, °R.

T_i —Initial absolute temperature of flask, °R.

6.2 Sample concentration. Read $\mu\text{g. NO}_x$ for each sample from the plot of $\mu\text{g. NO}_x$ versus absorbance.

$$C = \left(\frac{m}{V_{..}} \right) \left(\frac{1 \text{ lb.}}{\frac{\text{cu. ft.}}{1.6 \times 10^3 \frac{\mu\text{g.}}{\text{ml.}}}} \right) = \left(6.2 \times 10^{-3} \frac{\text{lb./s.c.f.}}{\mu\text{g./ml.}} \right) \left(\frac{m}{V_{..}} \right) \quad \text{equation 7-2}$$

where:

C —Concentration of NO_x as NO_2 (dry basis), lb./s.c.f.

m —Mass of NO_x in gas sample, $\mu\text{g.}$

$V_{..}$ —Sample volume at standard conditions (dry basis), ml.

7. References.

Standard Methods of Chemical Analysis. 6th ed. New York, D. Van Nostrand Co., Inc., 1962, vol. 1, p. 323-330.
Standard Method of Test for Oxides of Nitrogen in Gaseous Combustion Products

(Phenoldisulfonic Acid Procedure). In: 1968 Book of ASTM Standards, Part 23, Philadelphia, Pa. 1968, ASTM Designation D-1608-60, p. 725-729.

Jacob, M. B., The Chemical Analysis of Air Pollutants, New York, N.Y., Interscience Publishers, Inc., 1960, vol. 10, p. 351-356.

METHOD 8—DETERMINATION OF SULFURIC ACID MIST AND SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. A gas sample is extracted from a sampling point in the stack and the acid mist including sulfur trioxide is separated from sulfur dioxide. Both fractions are measured separately by the barium-thorin titration method.

1.2 Applicability. This method is applicable to determination of sulfuric acid mist (including sulfur trioxide) and sulfur dioxide from stationary sources only when specified by the test procedures for determining compliance with the New Source Performance Standards.

2. Apparatus.

2.1 Sampling. See Figure 8-1. Many of the design specifications of this sampling train are described in APTD-0581.

2.1.1 Nozzle—Stainless steel (316) with sharp, tapered leading edge.

2.1.2 Probe—Pyrex¹ glass with a heating system to prevent visible condensation during sampling.

2.1.3 Pitot tube—Type S, or equivalent, attached to probe to monitor stack gas velocity.

2.1.4 Filter holder—Pyrex¹ glass.

2.1.5 Impingers—Four as shown in Figure 8-1. The first and third are of the Greenburg-Smith design with standard tip. The second and fourth are of the Greenburg-Smith design, modified by replacing the standard tip with a 1/2-inch ID glass tube extending to one-half inch from the bottom of the impinger flask. Similar collection systems, which have been approved by the Administrator, may be used.

2.1.6 Metering system—Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 5° F., dry gas meter with 2% accuracy, and related equipment, or equivalent, as required to maintain an isokinetic sampling rate and to determine sample volume.

2.1.7 Barometer—To measure atmospheric pressure to ± 0.1 inch Hg.

¹ Trade name.

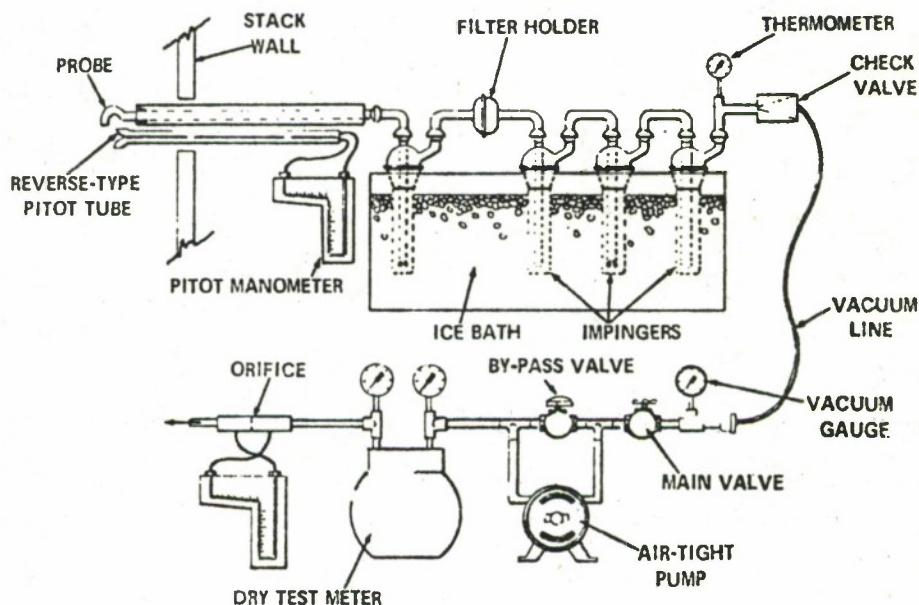


Figure 8-1. Sulfuric acid mist sampling train.

- 2.2 Sample recovery.
 - 2.2.1 Wash bottles—Two.
 - 2.2.2 Graduated cylinders—250 ml., 500 ml.
 - 2.2.3 Glass sample storage containers.
 - 2.2.4 Graduated cylinder—250 ml.
- 2.3 Analysis.
 - 2.3.1 Pipette—25 ml., 100 ml.
 - 2.3.2 Burette—50 ml.
 - 2.3.3 Erlenmeyer flask—250 ml.
 - 2.3.4 Graduated cylinder—100 ml.
 - 2.3.5 Trip balance—300 g. capacity, to measure to ± 0.05 g.
 - 2.3.6 Dropping bottle—to add indicator solution.

3. Reagents.

- 3.1 Sampling.
 - 3.1.1 Filters—Glass fiber, MSA type 1106 BH, or equivalent, of a suitable size to fit in the filter holder.
 - 3.1.2 Silica gel—Indicating type, 6-16 mesh, dried at 175° C. (350° F.) for 2 hours.
 - 3.1.3 Water—Deionized, distilled.
 - 3.1.4 Isopropanol, 80%—Mix 800 ml. of isopropanol with 200 ml. of deionized, distilled water.
 - 3.1.5 Hydrogen peroxide, 3%—Dilute 100 ml. of 30% hydrogen peroxide to 1 liter with deionized, distilled water.
 - 3.1.6 Crushed ice.
- 3.2 Sample recovery.
 - 3.2.1 Water—Deionized, distilled.
 - 3.2.2 Isopropanol, 80%.
- 3.3 Analysis.
 - 3.3.1 Water—Deionized, distilled.
 - 3.3.2 Isopropanol.
 - 3.3.3 Thorin indicator—1-(o-arsonophenylazo)-2-naphthol-3, 6-disulfonic acid, disodium salt (or equivalent). Dissolve 0.20 g. in 100 ml. distilled water.
 - 3.3.4 Barium perchlorate (0.01N)—Dissolve 1.95 g. of barium perchlorate [$\text{Ba}(\text{ClO}_4)_2 \cdot 3 \text{H}_2\text{O}$] in 200 ml. distilled water and dilute to 1 liter with isopropanol. Standardize with sulfuric acid.
 - 3.3.5 Sulfuric acid standard (0.01N)—Purchase or standardize to ± 0.0002 N against 0.01 N NaOH which has previously been standardized against primary standard potassium acid phthalate.

4. Procedure.

4.1 Sampling.

4.1.1 After selecting the sampling site and the minimum number of sampling points, determine the stack pressure, temperature, moisture, and range of velocity head.

4.1.2 Preparation of collection train. Place 100 ml. of 80% isopropanol in the first impinger, 100 ml. of 3% hydrogen peroxide in both the second and third impingers, and about 200 g. of silica gel in the fourth impinger. Retain a portion of the reagents for use as blank solutions. Assemble the train without the probe as shown in Figure 8-1 with the filter between the first and second impingers. Leak check the sampling train at the sampling site by plugging the inlet to the first impinger and pulling a 15-inch Hg vacuum. A leakage rate not in excess of 0.02 c.f.m. at a vacuum of 15 inches Hg is acceptable. Attach the probe and turn on the probe heating system. Adjust the probe heater setting during sampling to prevent any visible condensation. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the gases leaving the last impinger at 70° F. or less.

4.1.3 Train operation. For each run, record the data required on the example sheet shown in Figure 8-2. Take readings at each sampling point at least every 5 minutes and when significant changes in stack conditions necessitate additional adjustments in flow rate. To begin sampling, position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Start the pump and immediately adjust the flow to isokinetic conditions. Maintain isokinetic sampling throughout the sampling period. Nomographs are available which aid in the rapid adjustment of the sampling rate without other computations. APTD-0576 details the procedure for using these nomographs. At the conclusion of each run, turn off the pump and record the final readings. Remove the probe from the stack and disconnect it from the train. Drain the ice bath and purge the remaining part of the train by drawing clean ambient air through the system for 15 minutes.

Figure 8-2. Field data.

T_{std} —Absolute temperature at standard conditions, 530° R.

T_m —Average dry gas meter temperature, °R.

P_{bar} —Barometric pressure at the orifice meter, inches Hg.

ΔH —Pressure drop across the orifice meter, inches H₂O.

13.6—Specific gravity of mercury.

P_{std} —Absolute pressure at standard conditions, 29.92 inches Hg.

6.2 Sulfuric acid concentration.

$$C_{H_2SO_4} = \left(1.08 \times 10^{-4} \frac{\text{lb.-l.}}{\text{g.-ml.}} \right) \frac{(V_s - V_{tb})(N) \left(\frac{V_{soln}}{V_s} \right)}{V_{mstd}} \quad \text{equation 8-2}$$

$C_{H_2SO_4}$ —Concentration of sulfuric acid at standard conditions, dry basis, lb./cu. ft.

1.08×10^{-4} —Conversion factor including the number of grams per gram equivalent of sulfuric acid (49 g./g.-eq.), 453.6 g./lb., and 1,000 ml./l., lb.-l./g.-ml.

V_s —Volume of barium perchlorate titrant used for the sample, ml.

V_{tb} —Volume of barium perchlorate titrant used for the blank, ml.

N —Normality of barium perchlorate titrant, g.-eq./l.

V_{soln} —Total solution volume of sulfuric acid (first impinger and filter), ml.

V_s —Volume of sample aliquot titrated, ml.

V_{mstd} —Volume of gas sample through the dry gas meter (standard conditions), cu. ft., see Equation 8-1.

8.3 Sulfur dioxide concentration.

$$C_{SO_2} = \left(7.05 \times 10^{-5} \frac{\text{lb.-l.}}{\text{g.-ml.}} \right) \frac{(V_s - V_{tb})(N) \left(\frac{V_{soln}}{V_s} \right)}{V_{mstd}} \quad \text{equation 8-3}$$

where:

C_{SO_2} —Concentration of sulfur dioxide at standard conditions, dry basis, lb./cu. ft.

7.05×10^{-5} —Conversion factor including the number of grams per gram equivalent of sulfur dioxide (32 g./g.-eq.) 453.6 g./lb., and 1,000 ml./l., lb.-l./g.-ml.

V_s —Volume of barium perchlorate titrant used for the sample, ml.

V_{tb} —Volume of barium perchlorate titrant used for the blank, ml.

N —Normality of barium perchlorate titrant, g.-eq./l.

V_{soln} —Total solution volume of sulfur dioxide (second and third impingers), ml.

V_s —Volume of sample aliquot titrated, ml.

V_{mstd} —Volume of gas sample through the dry gas meter (standard conditions), cu. ft., see Equation 8-1.

7. References.

Atmospheric Emissions from Sulfuric Acid Manufacturing Processes, U.S. DHEW, PHS, Division of Air Pollution, Public Health Service Publication No. 999-AP-13, Cincinnati, Ohio, 1985.

Corbett, D. F., The Determination of SO₂ and SO₃ in Flue Gases, Journal of the Institute of Fuel, 24:237-243, 1981.

Martin, Robert M., Construction Details of Isokinetic Source Sampling Equipment, Environmental Protection Agency, Air Pollution Control Office Publication No. APTD-0581.

Patton, W. F., and J. A. Brink, Jr., New Equipment and Techniques for Sampling Chemical Process Gases, J. Air Pollution Control Assoc. 13, 162 (1963).

Rom, Jerome J., Maintenance, Calibration, and Operation of Isokinetic Source Sampling Equipment, Environmental Protection Agency, Air Pollution Control Office Publication No. APTD-0578.

Shell Development Co. Analytical Department, Determination of Sulfur Dioxide and Sulfur Trioxide in Stack Gases, Emeryville Method Series, 4518/59a.

METHOD 9—VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. The relative opacity of an emission from a stationary source is determined visually by a qualified observer.

1.2 Applicability. This method is applicable for the determination of the relative opacity of visible emissions from stationary sources only when specified by test procedures for determining compliance with the New Source Performance Standards.

2. Procedure.

2.1 The qualified observer stands at approximately two stack heights, but not more than a quarter of a mile from the base of the stack with the sun to his back. From a vantage point perpendicular to the plume the observer studies the point of greatest opacity in the plume. The data required in Figure 9-1 is recorded every 15 to 30 seconds to the nearest 5% opacity. A minimum of 25 readings is taken.

3. Qualifications.

3.1 To certify as an observer, a candidate must complete a smoke-reading course conducted by EPA, or equivalent; in order to certify the candidate must assign opacity readings in 5% increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15 percent on any one reading and an average error not to exceed 7.5 percent in each category. The smoke generator used to qualify the observers must be equipped with a calibrated smoke indicator or light transmission meter located in the source stack if the smoke

generator is to determine the actual opacity of the emissions. All qualified observers must pass this test every 6 months in order to remain certified.

4. Calculations.

4.1 Determine the average opacity.

5. References.

Air Pollution Control District Rules and Regulations, Los Angeles County Air Pollution Control District, Chapter 2, Schedule 6, Regulation 4, Prohibition, Rule 50, 17 p.

Kudluk, Rudolf, Ringelmann Smoke Chart, U.S. Department of Interior, Bureau of Mines, Information Circular No. 8333, May 1967.

SEC MIN	0	15	30	45	SEC MIN	0	15	30	45
0					30				
1					31				
2					32				
3					33				
4					34				
5					35				
6					36				
7					37				
8					38				
9					39				
10					40				
11					41				
12					42				
13					43				
14					44				
15					45				
16					46				
17					47				
18					48				
19					49				
20					50				
21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				

Observation date _____

Plant _____

Stack location _____

Observer _____

Date _____

Time _____

Distance to stack _____

Wind direction _____

Wind speed _____

Sum of numbers recorded _____

Total number of readings _____

Sum of nos. recorded _____

Opacity: _____

Total no. readings _____

Figure 9-1. Field data.

METHOD 10—DETERMINATION OF CARBON MONOXIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and Applicability.

1.1 *Principle.* An integrated or continuous gas sample is extracted from a sampling point and analyzed for carbon monoxide (CO) content using a Luft-type nondispersive infrared analyzer (NDIR) or equivalent.

1.2 *Applicability.* This method is applicable for the determination of carbon monoxide emissions from stationary sources only when specified by the test procedures for

determining compliance with new source performance standards. The test procedure will indicate whether a continuous or an integrated sample is to be used.

2. Range and sensitivity.

2.1 *Range.* 0 to 1,000 ppm.

2.2 *Sensitivity.* Minimum detectable concentration is 20 ppm for a 0 to 1,000 ppm span.

3. *Interferences.* Any substance having a strong absorption of infrared energy will interfere to some extent. For example, discrimination ratios for water (H₂O) and car-

bon dioxide (CO_2) are 3.5 percent H_2O per 7 ppm CO and 10 percent CO_2 per 10 ppm CO, respectively, for devices measuring in the 1,500 to 3,000 ppm range. For devices measuring in the 0 to 100 ppm range, interference ratios can be as high as 3.5 percent H_2O per 25 ppm CO and 10 percent CO_2 per 50 ppm CO. The use of silica gel and ascarite traps will alleviate the major interference problems. The measured gas volume must be corrected if these traps are used.

4. Precision and accuracy.

4.1 *Precision.* The precision of most NDIR analyzers is approximately ± 2 percent of span.

4.2 *Accuracy.* The accuracy of most NDIR analyzers is approximately ± 5 percent of span after calibration.

5. Apparatus.

5.1 Continuous sample (Figure 10-1).

5.1.1 *Probe.* Stainless steel or sheathed Pyrex¹ glass, equipped with a filter to remove particulate matter.

5.1.2 *Air-cooled condenser or equivalent.* To remove any excess moisture.

5.2 Integrated sample (Figure 10-2).

5.2.1 *Probe.* Stainless steel or sheathed Pyrex glass, equipped with a filter to remove particulate matter.

5.2.2 *Air-cooled condenser or equivalent.* To remove any excess moisture.

5.2.3 *Valve.* Needle valve, or equivalent, to adjust flow rate.

5.2.4 *Pump.* Leak-free diaphragm type, or equivalent, to transport gas.

5.2.5 *Rate meter.* Rotameter, or equivalent, to measure a flow range from 0 to 1.0 liter per min. (0.035 cfm).

5.2.6 *Flexible bag.* Tedlar, or equivalent, with a capacity of 60 to 90 liters (2 to 3 ft³). Leak-test the bag in the laboratory before using by evacuating bag with a pump followed by a dry gas meter. When evacuation is complete, there should be no flow through the meter.

5.2.7 *Pitot tube.* Type S, or equivalent, attached to the probe so that the sampling rate can be regulated proportional to the stack gas velocity when velocity is varying with the time or a sample traverse is conducted.

5.3 Analysis (Figure 10-3).

5.3.1 *Carbon monoxide analyzer.* Nondispersive infrared spectrometer, or equivalent. This instrument should be demonstrated, preferably by the manufacturer, to meet or exceed manufacturer's specifications and those described in this method.

5.3.2 *Drying tube.* To contain approximately 200 g of silica gel.

5.3.3 *Calibration gas.* Refer to paragraph 6.1.

5.3.4 *Filter.* As recommended by NDIR manufacturer.

¹ Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

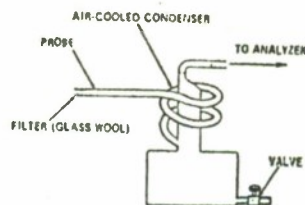


Figure 10-1. Continuous sampling train.

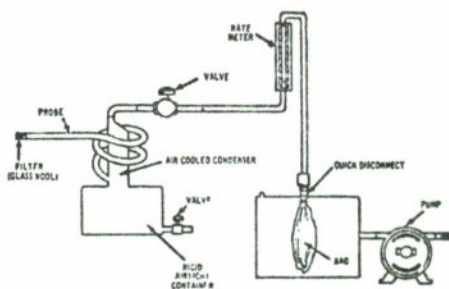


Figure 10-2. Integrated gas sampling train.

5.3.5 *CO_2 removal tube.* To contain approximately 500 g of ascarite.

5.3.6 *Ice water bath.* For ascarite and silica gel tubes.

5.3.7 *Valve.* Needle valve, or equivalent, to adjust flow rate.

5.3.8 *Rate meter.* Rotameter or equivalent to measure gas flow rate of 0 to 1.0 liter per min. (0.035 cfm) through NDIR.

5.3.9 *Recorder (optional).* To provide permanent record of NDIR readings.

6. Reagents.

6.1 *Calibration gases.* Known concentration of CO in nitrogen (N_2) for instrument span, prepurified grade of N_2 for zero, and two additional concentrations corresponding approximately to 60 percent and 30 percent span. The span concentration shall not exceed 1.5 times the applicable source performance standard. The calibration gases shall be certified by the manufacturer to be within ± 2 percent of the specified concentration.

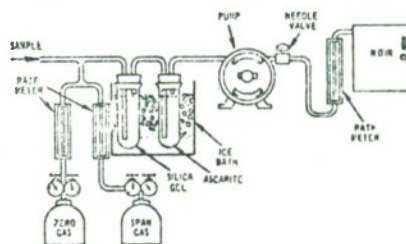


Figure 10-3. Analytical equipment.

6.2 *Silica gel*. Indicating type, 6 to 16 mesh, dried at 175° C (347° F) for 2 hours.

6.3 *Ascarite*. Commercially available.

7. Procedure.

7.1 Sampling.

7.1.1 *Continuous sampling*. Set up the equipment as shown in Figure 10-1 making sure all connections are leak free. Place the probe in the stack at a sampling point and purge the sampling line. Connect the analyzer and begin drawing sample into the analyzer. Allow 5 minutes for the system to stabilize, then record the analyzer reading as required by the test procedure. (See ¶ 7.2 and 8). CO₂ content of the gas may be determined by using the Method 3 integrated sample procedure (36 FR 24886), or by weighing the ascarite CO₂ removal tube and computing CO₂ concentration from the gas volume sampled and the weight gain of the tube.

7.1.2 *Integrated sampling*. Evacuate the flexible bag. Set up the equipment as shown in Figure 10-2 with the bag disconnected. Place the probe in the stack and purge the sampling line. Connect the bag, making sure that all connections are leak free. Sample at a rate proportional to the stack velocity. CO₂ content of the gas may be determined by using the Method 3 integrated sample

procedures (36 FR 24886), or by weighing the ascarite CO₂ removal tube and computing CO₂ concentration from the gas volume sampled and the weight gain of the tube.

7.2 *CO Analysis*. Assemble the apparatus as shown in Figure 10-3, calibrate the instrument, and perform other required operations as described in paragraph 8. Purge analyzer with N₂ prior to introduction of each sample. Direct the sample stream through the instrument for the test period, recording the readings. Check the zero and span again after the test to assure that any drift or malfunction is detected. Record the sample data on Table 10-1.

8. *Calibration*. Assemble the apparatus according to Figure 10-3. Generally an instrument requires a warm-up period before stability is obtained. Follow the manufacturer's instructions for specific procedure. Allow a minimum time of one hour for warm-up. During this time check the sample conditioning apparatus, i.e., filter, condenser, drying tube, and CO₂ removal tube, to ensure that each component is in good operating condition. Zero and calibrate the instrument according to the manufacturer's procedures using, respectively, nitrogen and the calibration gases.

TABLE 10-1.—Field data

Location	Comments:
Test	
Date	
Operator	
Clock time	Rotameter setting, liters per minute (cubic feet per minute)

9. *Calculation—Concentration of carbon monoxide*. Calculate the concentration of carbon monoxide in the stack using equation 10-1.

$$C_{CO,stack} = C_{CO,NDIR}(1 - F_{CO_2}) \quad \text{equation 10-1}$$

where:

$C_{CO,stack}$ = concentration of CO in stack, ppm by volume (dry basis).

$C_{CO,NDIR}$ = concentration of CO measured by NDIR analyzer, ppm by volume (dry basis).

F_{CO_2} = volume fraction of CO₂ in sample, i.e., percent CO₂ from Orsat analysis divided by 100.

10. Bibliography.

- 10.1 McElroy, Frank, The Intertech NDIR-CO Analyzer, Presented at 11th Methods Conference on Air Pollution, University of California, Berkeley, Calif., April 1, 1970.
- 10.2 Jacobs, M. B., et al., Continuous Determination of Carbon Monoxide and Hy-

- drocarbons in Air by a Modified Infrared Analyzer, J. Air Pollution Control Association, 9(2):110-114, August 1959.
- 10.3 MSA LIRA Infrared Gas and Liquid Analyzer Instruction Book, Mine Safety Appliances Co., Technical Products Division, Pittsburgh, Pa.

App. A

Title 40—Protection of Environment

10.4 Models 215A, 315A, and 415A Infrared Analyzers, Beckman Instruments, Inc., Beckman Instructions 1635-B, Fullerton, Calif., October 1967.

10.5 Continuous CO Monitoring System, Model A5611, Intertech Corp., Princeton, N.J.

10.6 UNOR Infrared Gas Analyzers, Bendix Corp., Ronceverte, West Virginia.

ADDENDA

A. Performance Specifications for NDIR Carbon Monoxide Analyzers.

Range (minimum)-----	0-1000ppm.
Output (minimum)-----	0-10mV.
Minimum detectable sensitivity-----	20 ppm.
Rise time, 90 percent (maximum)-----	30 seconds.
Fall time, 90 percent (maximum)-----	30 seconds.
Zero drift (maximum)-----	10% in 8 hours.
Span drift (maximum)-----	10% in 8 hours.
Precision (minimum)-----	± 2% of full scale.
Noise (maximum)-----	± 1% of full scale.
Linearity (maximum deviation)-----	2% of full scale.
Interference rejection ratio-----	CO ₂ —1000 to 1, H ₂ O—500 to 1.

B. Definitions of Performance Specifications.

Range—The minimum and maximum measurement limits.

Output—Electrical signal which is proportional to the measurement; intended for connection to readout or data processing devices. Usually expressed as millivolts or milliamperes full scale at a given impedance.

Full scale—The maximum measuring limit for a given range.

Minimum detectable sensitivity—The smallest amount of input concentration that can be detected as the concentration approaches zero.

Accuracy—The degree of agreement between a measured value and the true value; usually expressed as ± percent of full scale.

Time to 90 percent response—The time interval from a step change in the input concentration at the instrument inlet to a reading of 90 percent of the ultimate recorded concentration.

Rise Time (90 percent)—The interval between initial response time and time to 90 percent response after a step increase in the inlet concentration.

Fall Time (90 percent)—The interval between initial response time and time to 90 percent response after a step decrease in the inlet concentration.

Zero Drift—The change in instrument output over a stated time period, usually 24 hours, of unadjusted continuous operation when the input concentration is zero; usually expressed as percent full scale.

Span Drift—The change in instrument output over a stated time period, usually 24 hours, of unadjusted continuous operation when the input concentration is a stated upscale value; usually expressed as percent full scale.

Precision—The degree of agreement between repeated measurements of the same concentration, expressed as the average deviation of the single results from the mean.

Noise—Spontaneous deviations from a mean output not caused by input concentration changes.

Linearity—The maximum deviation between an actual instrument reading and the reading predicted by a straight line drawn between upper and lower calibration points.

METHOD 11—DETERMINATION OF HYDROGEN SULFIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 **Principle.** Hydrogen sulfide (H₂S) is collected from the source in a series of midjet impingers and reacted with alkaline cadmium hydroxide [Cd(OH)₂] to form cadmium sulfide (CdS). The precipitated CdS is then dissolved in hydrochloric acid and absorbed in a known volume of iodine solution. The iodine consumed is a measure of the H₂S content of the gas. An impinger containing hydrogen peroxide is included to remove SO₂ as an interfering species.

1.2 **Applicability.** This method is applicable for the determination of hydrogen sulfide emissions from stationary sources only when specified by the test procedures for determining compliance with the new source performance standards.

2. Apparatus.

2.1 Sampling train.

2.1.1 **Sampling line**—6- to 7-mm (¼-inch) Teflon¹ tubing to connect sampling train to sampling valve, with provisions for heating to prevent condensation. A pressure reducing valve prior to the Teflon sampling line may be required depending on sampling stream pressure.

2.1.2 **Impingers**—Five midjet impingers, each with 30-ml capacity, or equivalent.

2.1.3 **Ice bath container**—To maintain absorbing solution at a constant temperature.

2.1.4 **Silica gel drying tube**—To protect pump and dry gas meter.

¹ Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

2.1.5 *Needle valve, or equivalent*—Stainless steel or other corrosion resistant material, to adjust gas flow rate.

2.1.6 *Pump*—Leak free, diaphragm type, or equivalent, to transport gas. (Not required if sampling stream under positive pressure.)

2.1.7 *Dry gas meter*—Sufficiently accurate to measure sample volume to within 1 percent.

2.1.8 *Rate meter*—Rotameter, or equivalent, to measure a flow rate of 0 to 3 liters per minute (0.1 ft³/min).

2.1.9 *Graduated cylinder*—25 ml.

2.1.10 *Barometer*—To measure atmospheric pressure within ± 2.5 mm (0.1 in.) Hg.

2.2 *Sample Recovery.*

2.2.1 *Sample container*—500-ml glass-stoppered iodine flask.

2.2.2 *Pipette*—50-ml volumetric type.

2.2.3 *Beckers*—250 ml.

2.2.4 *Wash bottle*—Glass.

2.3 *Analysis.*

2.3.1 *Flask*—500-ml glass-stoppered iodine flask.

2.3.2 *Burette*—One 60 ml.

2.3.2 *Flask*—125-ml conical.

3. *Reagents.*

3.1 *Sampling.*

3.1.1 *Absorbing solution*—Cadmium hydroxide ($\text{Cd}(\text{OH})_2$)—Mix 4.3 g cadmium sulfate hydrate ($3 \text{ CdSO}_4 \cdot 8 \text{ H}_2\text{O}$) and 0.3 g of sodium hydroxide (NaOH) in 1 liter of distilled water (H_2O). Mix well.

Note: The cadmium hydroxide formed in this mixture will precipitate as a white suspension. Therefore, this solution must be thoroughly mixed before using to ensure an even distribution of the cadmium hydroxide.

3.1.2 *Hydrogen peroxide, 3 percent*—Dilute 30 percent hydrogen peroxide to 3 percent as needed. Prepare fresh daily;

3.2 *Sample recovery.*

3.2.1 *Hydrochloric acid solution (HCl), 10 percent by weight*—Mix 230 ml of concentrated HCl (specific gravity 1.19) and 770 ml of distilled H_2O .

3.2.2 *Iodine solution, 0.1 N*—Dissolve 24 g potassium iodide (KI) in 30 ml of distilled H_2O in a 1-liter graduated cylinder. Weigh 12.7 g of resublimed iodine (I_2) into a weighing bottle and add to the potassium iodide solution. Shake the mixture until the iodine is completely dissolved. Slowly dilute the solution to 1 liter with distilled H_2O , with swirling. Filter the solution, if cloudy, and store in a brown glass-stoppered bottle.

3.2.3 *Standard iodine solution, 0.01 N*—Dilute 100 ml of the 0.1 N iodine solution in a volumetric flask to 1 liter with distilled water.

Standardize daily as follows: Pipette 25 ml of the 0.01 N iodine solution into a 125-ml conical flask. Titrate with standard 0.01 N thiosulfate solution (see paragraph 3.3.2) until the solution is a light yellow. Add a few drops of the starch solution and continue titrating until the blue color just disappears. From the results of this titration, calculate

the exact normality of the iodine solution (see paragraph 5.1).

3.2.4 *Distilled, deionized water.*

3.3 *Analysis.*

3.3.1 *Sodium thiosulfate solution, standard 0.1 N*—For each liter of solution, dissolve 24.8 g of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{ H}_2\text{O}$) in distilled water and add 0.01 g of anhydrous sodium carbonate (Na_2CO_3) and 0.4 ml of chloroform (CHCl_3) to stabilize. Mix thoroughly by shaking or by aerating with nitrogen for approximately 15 minutes, and store in a glass-stoppered glass bottle.

Standardize frequently as follows: Weigh into a 500-ml volumetric flask about 2 g of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) weighed to the nearest milligram and dilute to the 500-ml mark with distilled H_2O . Use dichromate which has been crystallized from distilled water and oven-dried at 182°C to 199°C (360°F to 390°F). Dissolve approximately 3 g of potassium iodide (KI) in 50 ml of distilled water in a glass-stoppered, 500-ml conical flask, then add 5 ml of 20-percent hydrochloric acid solution. Pipette 50 ml of the dichromate solution into this mixture. Gently swirl the solution once and allow it to stand in the dark for 5 minutes. Dilute the solution with 100 to 200 ml of distilled water, washing down the sides of the flask with part of the water. Swirl the solution slowly and titrate with the thiosulfate solution until the solution is light yellow. Add 4 ml of starch solution and continue with a slow titration with the thiosulfate until the bright blue color has disappeared and only the pale green color of the chromic ion remains. From this titration, calculate the exact normality of the sodium thiosulfate solution (see paragraph 5.2).

3.3.2 *Sodium thiosulfate solution, standard 0.01 N*—Pipette 100 ml of the standard 0.1 N thiosulfate solution into a volumetric flask and dilute to one liter with distilled water.

3.3.3 *Starch indicator solution*—Suspend 10 g of soluble starch in 100 ml of distilled water and add 15 g of potassium hydroxide pellets. Stir until dissolved, dilute with 900 ml of distilled water, and let stand 1 hour. Neutralize the solution with concentrated hydrochloric acid, using an indicator paper similar to Alkacid test ribbon, then add 2 ml of glacial acetic acid as a preservative.

Test for decomposition by titrating 4 ml of starch solution in 200 ml of distilled water with 0.01 N iodine solution. If more than 4 drops of the 0.01 N iodine solution are required to obtain the blue color, make up a fresh starch solution.

4. *Procedure.*

4.1 *Sampling.*

4.1.1 Assemble the sampling train as shown in Figure 11-1, connecting the five midjet impingers in series. Place 15 ml of 3 percent hydrogen peroxide in the first impinger. Place 15 ml of the absorbing solution in each of the next three impingers, leaving the fifth dry. Place crushed ice around the impingers.

4.1.2 Purge the connecting line between the sampling valve and the first impinger. Connect the sample line to the train. Record the initial reading on the dry gas meter as shown in Table 11-1.

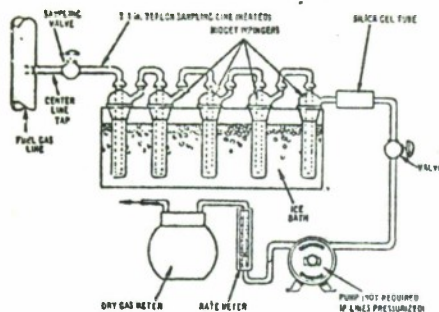


Figure 11-1. H₂S sampling train

TABLE 11-1.—Field data

Location ----- Comments:
 Test -----
 Date -----
 Operator -----
 Barometric pressure--

Clock time	Gas volume through meter (V_m), liters (cubic feet)	Rotameter setting, Lpm (cubic feet per minute)	Meter temperature, ° C (° F)
---------------	---	---	------------------------------------

4.1.4 Continue sampling a minimum of 10 minutes. If the yellow color of cadmium sulfide is visible in the third Impinger, analysis should confirm that the applicable standard has been exceeded. At the end of the sample time, close the flow control valve and read the final meter volume and temperature.

4.2 Sample recovery.

4.2.2 Discard the contents of the hydrogen peroxide impinger. Carefully transfer the contents of the remaining four impingers to a 500-ml iodine flask.

4.2.4 Follow this rinse with two more rinses using distilled water. Add the distilled water rinses to the Iodine flask. Stopper the flask and shake well. Allow about 30 minutes for absorption of the H_2S into the Iodine, then complete the analysis titration.

4.2.5 Prepare a blank in an iodine flask using 45 ml of the absorbing solution, 50 ml of 0.01 N iodine solution, and 50 ml of 10 percent HCl. Stopper the flask, shake well and analyze with the samples.

4.3 Analysis.

Note: This analysis titration should be conducted at the sampling location in order to prevent loss of iodine from the sample. Titration should never be made in direct sunlight.

4.3.1 Titrate the solution in the flask with 0.01 N sodium thiosulfate solution until the solution is light yellow. Add 4 ml of the starch indicator solution and continue titrating until the blue color just disappears.

4.3.2 Titrate the blanks in the same manner as the samples.

5. Calculations.

5.1 Normality of the standard iodine solution.

$$N_I = \frac{N_T V_T}{V_I} \quad \text{equation 11-1}$$

where:

 N_I = normality of iodine, g-eq/liter. V_I = volume of iodine used, ml. N_T = normality of sodium thiosulfate, g-eq/liter. V_T = volume of sodium thiosulfate used, ml.

5.2 Normality of the standard thiosulfate solution.

$$N_T = 2.04 \frac{W}{V_T} \quad \text{equation 11-2}$$

where:

 W = weight of $K_2Cr_2O_7$ used, g. V_T = volume of $Na_2S_2O_3$ used, ml. N_T = normality of standard thiosulfate solution, g-eq/liter.

2.04 = conversion factor

$$= \frac{(6 \text{ eq } I_2/\text{mole } K_2Cr_2O_7) (1,000 \text{ ml/l})}{(294.2 \text{ g } K_2Cr_2O_7/\text{mole}) (10 \text{ aliquot factor})}$$

5.3 Dry gas volume. Correct the sample volume measured by the dry gas meter to standard conditions [$21^\circ\text{C}(70^\circ\text{F})$] and 760 mm (29.92 inches) Hg] by using equation 11-3.

$$V_{mstd} = V_m \left(\frac{T_{std}}{T_m} \right) \left(\frac{P_{bar}}{P_{std}} \right) \quad \text{equation 11-3}$$

where:

 V_{mstd} = volume at standard conditions of gas sample through the dry gas meter,

standard liters (scf).

 V_m = volume of gas sample through the dry gas meter (meter conditions), liters (cu. ft.). T_{std} = absolute temperature at standard conditions, 294°K (530°R). T_m = average dry gas meter temperature, $^\circ\text{K}$ ($^\circ\text{R}$). P_{bar} = barometric pressure at the orifice meter, mm Hg (in. Hg). P_{std} = absolute pressure at standard conditions, 760 mm Hg (29.92 in. Hg).

5.4 Concentration of H_2S .—Calculate the concentration of H_2S in the gas stream at standard conditions using equation 11-4:

$$C_{H_2S} = \frac{K[(V_I N_I - V_T N_T)_{\text{sample}} - (V_I N_I - V_T N_T)_{\text{blank}}]}{V_{mstd}}$$

where (metric units):

 C_{H_2S} = concentration of H_2S at standard conditions, mg/dscm K = conversion factor = 17.0×10^3

$$= \frac{(34.07 \text{ g/mole } H_2S)(1,000 \text{ l/m}^3)(1,000 \text{ mg/g})}{(1,000 \text{ ml/l})(2H_2S \text{ eq/mole})}$$

 V_I = volume of standard iodine solution, ml. N_I = normality of standard iodine solution, g-eq/liter. V_T = volume of standard sodium thiosulfate solution, ml. N_T = normality of standard sodium thiosulfate solution, g-eq/liter. V_{mstd} = dry gas volume at standard conditions, liters.

where (English units):

$$K = 0.263 = \frac{17.0(15.43 \text{ gr/g})}{(1,000 \text{ l/m}^3)}$$

 V_{mstd} = scf. C_{H_2S} = gr/dscf.

6. References.

6.1 Determination of Hydrogen Sulfide, Ammoniacal Cadmium Chloride Method, API Method 772-54. In: Manual on Disposal of Refinery Wastes, Vol. V: Sampling and Analysis of Waste Gases and Particulate Matter, American Petroleum Institute, Washington, D.C., 1954.

6.2 Tentative Method for Determination of Hydrogen Sulfide and Mercaptan Sulfur in Natural Gas, Natural Gas Processors Association, Tulsa, Oklahoma, NGPA Publication No. 2265-65, 1965.

[36 FR 24877, Dec. 23, 1971; as amended at 38 FR 13562, May 23, 1973; 39 FR 9319, Mar. 8, 1974; 39 FR 13776, Apr. 17, 1974; 39 FR 20794, June 14, 1974]

PART 61—NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

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- 61.02 Definitions.
- 61.03 Abbreviations.
- 61.04 Address.
- 61.05 Prohibited activities.
- 61.06 Determination of construction or modification.
- 61.07 Application for approval of construction or modification.
- 61.08 Approval by Administrator.
- 61.09 Notification of startup.
- 61.10 Source reporting and waiver request.
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- 61.13 Waiver of emission tests.
- 61.14 Source test and analytical methods.
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Subpart B—National Emission Standard for Asbestos

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Subpart D—National Emission Standard for Beryllium Rocket Motor Firing

- 61.40 Applicability.
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Subpart E—National Emission Standard for Mercury

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- Appendix A—Compliance Status Information.
Appendix B—Test Methods.

Method 101—Reference method for determination of particulate and gaseous mercury emissions from stationary sources (air streams).

Method 102—Reference method for determination of particulate and gaseous mercury emissions from stationary sources (hydrogen streams).

Method 103—Beryllium screening method.

Method 104—Reference method for determination of beryllium emissions from stationary sources.

AUTHORITY: 42 U.S.C. 1857c-7.

SOURCE: 38 FR 8826, Apr. 6, 1973, unless otherwise noted.

Subpart A—General Provisions

§ 61.01 Applicability.

The provisions of this part apply to the owner or operator of any stationary source for which a standard is prescribed under this part.

§ 61.02 Definitions.

As used in this part, all terms not defined herein shall have the meaning given them in the act:

(a) "Act" means the Clean Air Act (42 U.S.C. 1857 et seq.).

(b) "Administrator" means the Administrator of the Environmental Protection Agency or his authorized representative.

(c) "Alternative method" means any method of sampling and analyzing for an air pollutant which is not a reference method or an equivalent method but which has been demonstrated to the Administrator's satisfaction to produce, in specific cases, results adequate for his determination of compliance.

(d) "Commenced" means that an owner or operator has undertaken a continuous program of construction or modification or that an owner or operator has entered into a contractual obligation to undertake and complete, within a reasonable time, a continuous program of construction or modification.

APPENDIX B

DISTRICT OF COLUMBIA AIR REGULATIONS

(A) To a source which is presently in compliance with paragraph (d) 1 of this section and which has certified such compliance to the Commissioner by June 1, 1974. The Commissioner may request whatever information he considers necessary for proper certification.

(B) To a source whose owner or operator submits to the Commissioner by June 1, 1974, a proposed alternative schedule. No such schedule may provide for compliance after May 31, 1977. If promulgated by the Commissioner, such schedule shall satisfy the requirements of this paragraph for the affected source.

(e) *Dry Cleaning Operation:*

(1) No person shall operate a dry cleaning operation using other than perchloroethylene, 1, 1, 1-trichloroethane, or saturated halogenated hydrocarbons unless the uncontrolled organic emissions from such operation are reduced at least 85 percent; provided that dry cleaning operations emitting less than three pounds per hour and less than 15 pounds per day of uncontrolled organic materials are exempt from the requirement of this section.

(2) If incineration is used as a control technique, 90 percent or more of the carbon in the organic emissions being incinerated must be oxidized to carbon dioxide.

(3) Any owner or operator of a source subject to this section shall achieve compliance with the requirements of paragraph (1) 1 of this section by discontinuing the use of photochemically reactive solvents no later than April 1, 1974, or by controlling emissions as required by paragraphs (1) and (2) of this section no later than May 31, 1975.

(f) *Organic Solvents:*

(1) No person shall discharge into the atmosphere more than 15 pounds of photochemically reactive solvents in any one day, no more than 3 pounds in any one hour, from any article, machine, equipment or other contrivance, unless the uncontrolled organic emissions are reduced by at least 85 percent.

(2) No person shall discharge into the atmosphere more than 40 pounds of non-photochemically reactive solvents in any one day, nor more than 8 pounds in any one hour, from any article, machine, equipment or other

contrivance, unless the uncontrolled organic emissions are reduced by at least 85 percent. Dry cleaning operations are exempt from the requirements of this paragraph.

(g) *Pumps and Compressors.* All pumps and compressors handling volatile organic compounds shall have mechanical seals or other equivalent equipment approved by the Commissioner.

(h) *Waste Gas Disposal from Ethylene Producing Plant.* No person shall cause, suffer, or allow the emission of a waste gas stream from any ethylene producing plant, or source utilizing ethylene as a raw material, into the atmosphere in excess of 20 pounds per 24-hour period, unless the waste gas stream is properly burned at 1,300 degrees Fahrenheit for 0.3 of a second or longer in a direct flame after-burner, or is removed by a method of comparable efficiency approved by the Commissioner.

(i) *Waste Gas Disposal from Vapor Blow-Down System.* No person shall emit hydrocarbon gases into the atmosphere from a vapor blow-down system, unless these gases are burned by smokeless flares, or an equally effective control device approved by the Commissioner, but this subsection shall not apply to accidental or emergency emissions of hydrocarbons needed for safe operation of equipment and processes.

Section 8-2:703 FUEL-BURNING PARTICULATE EMISSION.

No person shall cause, suffer, or allow to be emitted into the outdoor atmosphere from any fuel-burning equipment or premises, or to pass from a stack, particulate matter in the gases which exceeds 0.13 pounds per 1,000,000 B.T.U. heat input for installations using less than 3,500,000 B.T.U. per hour total input. For installations using more than 3,500,000 B.T.U. per hour total input, the particulate emission limitation shall decrease as the rate of heat input increases, according to the scales in Figure No. 1, contained hereinafter in Appendix No. 1.

Section 8-2:709 INCINERATORS.

(a) *Single Chamber and Fuel-Fed Incinerators.* The use of single chamber and fuel-fed incinerators is prohibited.

applicable air pollution standards, regulations, and laws. Monitoring information shall be supplied as the Commissioner may require in accordance with subsection (a) of this section.

(d) *Prohibited Devices.* No person shall install or use any article, machine, equipment, device, or other contrivance which conceals an emission from any source.

Section 8-2-718. SAMPLING, TESTS, AND MEASUREMENTS

(a) *General.* The Commissioner may conduct or cause to be conducted, or require an owner or operator to conduct, tests of emission of air pollutants from any source. Upon request to the Commissioner, the person responsible for the source to be tested shall provide necessary holes in stacks or ducts and such other safe and proper sampling and testing facilities as may be necessary for proper determination of the emission of air pollutants. The Commissioner may take or cause to be taken samples of fuel by any appropriate means, in such quantities as he feels are necessary for purposes of determining compliance with this regulation.

(b) *Particulate Matter.* Stack tests for particulate matter shall be undertaken by generally recognized standards or methods of measurement. Methods found in the American Society of Mechanical Engineers Test Code for Dust Separating Apparatus, PTC 21-1941, the American Society of Mechanical Engineers Test Code for Determining Dust Concentration in Gas Streams, PTC 27-1957, and the Los Angeles County California Source Testing Manual

shall be used, but such methods may be modified or adjusted by the Commissioner to suit specific sampling conditions or needs based upon good practice, judgment, and experience.

(c) *Sulfur.* The method for determining the sulfur content of fuel oil shall be that described in the American Society for Testing and Materials publication, D-129-64, "Standard Method of Test for Sulfur in Petroleum Products and Lubrications by the Bomb Method." The method for determining the sulfur content of coal shall be that described in the American Society for Testing and Materials publication, D-271-64, "Laboratory Sampling and Analysis of Coal and Coke." Equivalent methods may be approved by the Commissioner.

(d) *Visible Emissions.* The Ringelmann Smoke Chart published and described in the United States Bureau of Mines Information Circular 8333, or any other chart, record, indicator or device approved by the Commissioner for the measurement of plume density shall be used in determining the grade of shade or opacity of visible air contamination emissions.

(e) *Odor.*

(1) Odor measurements shall be made with a scentometer, such as that manufactured by the Barneby-Cheney Company, or by any device approved by the Commissioner as an effective instrument in the detection of odor.

(2) The odor strength as detected by the Barneby-Cheney Scentometer is that number corresponding to the maximum dilution when an odor is perceived on the following basis:

<u>Number</u>	<u>Odor-Bearing Air</u>		<u>Odor-Free Air</u>
1	1 part	to	1 part
2	1 part	to	2 parts
3	1 part	to	8 parts
4	1 part	to	32 parts
5	1 part	to	128 parts

(f) *Availability of Publications.* The publications cited in this section shall be kept on file at the office of the Director of the Department of Environmental Services and shall be available for public inspection.

Section 8-2-719. EMERGENCIES.

(a) *Establishment of Emergency Episode Plan.*

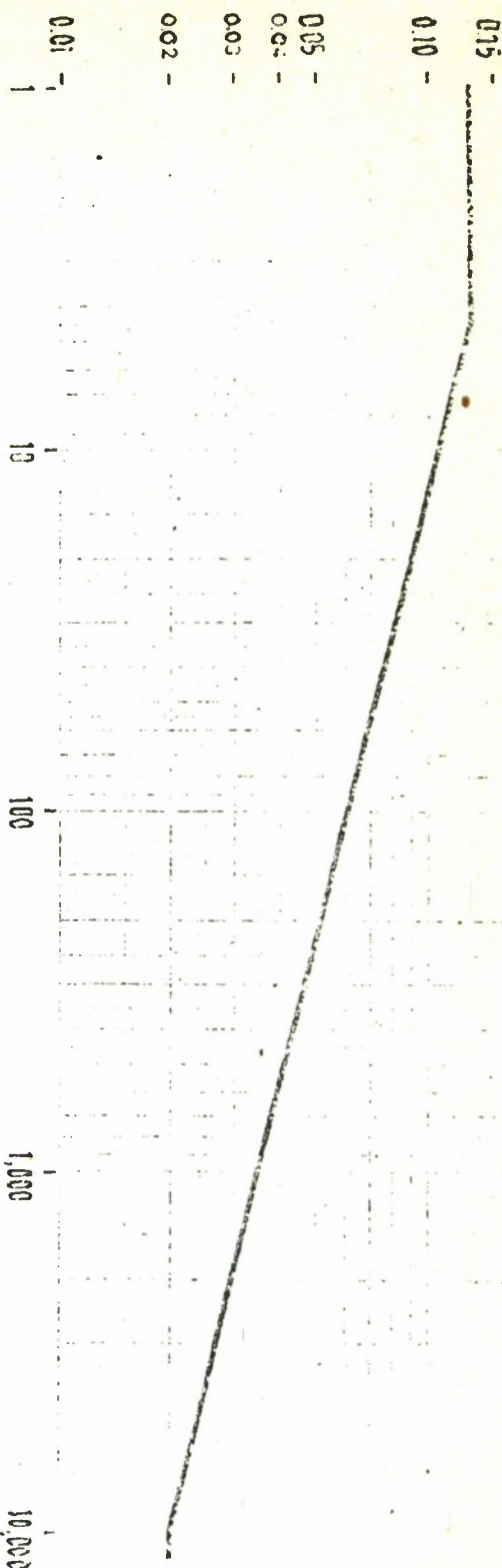
(1) The Commissioner shall after notice of not less than 30 days in the District Register and public hearing in accordance with section 8(a)(3) of the Act, establish such procedures as may be necessary to enable him, acting alone, or with air pollution control agencies of surrounding jurisdictions, to effectively deal with an air pollution emergency. The plan and any amendments thereto shall be submitted to the District of Columbia Council and shall not take effect unless approved by resolution of the Council. The plan shall be denominated the "Emergency Episode Plan," shall be kept on file by the Commissioner and shall be available for public inspection.

(2) *Declaration of an Episode Stage.* Whenever the Commissioner finds an emergency exists requiring immediate action to protect the public health or welfare, the Commissioner may, without notice or hearing, issue an order reciting the basis for the existence of such emergency, the episode stage at which the emergency exists, and requiring that such action be taken as is necessary to meet the emergency. Until subsection (a) (1) is fulfilled the Commissioner may declare an episode stage based solely on deteriorating air quality, where such action is necessary to protect the public health and welfare.

(3) *Individual Abatement Plan.* The Commissioner may require the owner or operator of a source of air pollution to prepare a written plan for reducing the emission of air pollution during an episode stage according to the guidelines set forth in the Emergency Episode Plan.

A. Such plan shall identify the source of air pollutants, and contain a brief description of the manner in which the reduction will be achieved during each episode stage.

B-3

 $E(\text{lb}/10^6 \text{ BTU})$ 

H-TOTAL HEAT INPUT IN MILLIONS OF BTU PER HR.

 $H(10^6 \text{ BTU/HR.})$ $H \leq 3.5; E = 0.15$ $3.5 < H < 10,000; E = 0.17455 H^{-0.23522}$ $H \geq 10,000; E = 0.02$

E-PARTICULATE EMISSION IN POUNDS OF PARTICULATE MATTER PER MILLION BTU HEAT INPUT

H (10^6 BTU/HR.)	E ($\text{lb}/10^6 \text{ BTU}$)
3.5	0.15
10	0.05
100	0.02
1,000	0.02
10,000	0.02

B-3

APPENDIX C

PARTICULATE SAMPLING DATA

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB DC Date: 6 May 1975

Test: #1

A. Particulate: _____ Total Gain 74.58 mg

1. Filter #79 Initial Wt .6784 Final Wt .72669 Gain 48.29

2. Acetone Rinse, Front Half

Initial Wt 10.28629 Final Wt 10.31258 Gain 26.29 mg

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 87.7 g

1. Impinger 1 - Initial Wt 643.4 Final Wt 747.9 Gain 104.5

2. Impinger 2 - Initial Wt 598.1 Final Wt 559.5 Gain (38.6)

3. Impinger 3 - Initial Wt 476.9 Final Wt 479.9 Gain 3.0

4. Impinger 4 - Initial Wt 710.6 Final Wt 728.8 Gain 18.2

~~5. Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____~~

C.	CO ₂	O ₂	CO	Time
	<u>5.0</u>	<u>12.8</u>	<u>0.0</u>	<u>1153</u>
	<u>4.6</u>	<u>12.4</u>	<u>0.0</u>	<u>1220</u>
	<u>4.8</u>	<u>12.6</u>	<u>0.0</u>	<u>1245</u>
	<u>4.8</u>	<u>12.8</u>	<u>0.0</u>	<u>1300</u>
	<u>5.0</u>	<u>13.8</u>	<u>0.0</u>	<u>1335</u>
	<u>4.6</u>	<u>14.2</u>	<u>0.0</u>	<u>1345</u>
	<u>4.2</u>	<u>14.0</u>	<u>0.0</u>	<u>1410</u>
Avg:	<u>4.7</u>	<u>13.23</u>	<u>0.0</u>	

D. Fuel Consumption: 1046 lbs/hr

#4 Fuel Oil Type

Engineer Capt M. L. Sweigart

Technician Sgt Conway

Table C-1 (Cont)

PARTICULATE SAMPLING DATA SHEET

Run No. 2
Date 6 May 1975

Plant C.B. Heating
Base Bolling AFB

Sample Box No. 2
Meter Box No. 3

Ambient Temp. 80°
Barometric Press. 29.52

Heater Box Setting 300
Probe Heater Setting Full

Probe Length Medium
Nozzle Area 7.616x10⁻⁴
Cp 2 0.846

EQUATIONS

$$H = K \cdot VP$$

$$K = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A^2}{Co} \right] \frac{Tm}{Ts}$$

$$\begin{aligned} QW/QM &= \frac{0.9394}{0.7882} = \frac{(5130)(.947)(.846)(7.616 \times 10^{-4})}{0.7882} \\ Co &= 0.7882 \end{aligned}$$

Schematic of Stack Cross Section

$$= 15.77 \frac{Tm}{Ts}$$

Traverse Point Number	Sampling Time	Static Pressure	Stack Temperature	Velocity Head	Orifice Diff. Pressure	Gas Sample Volume	Gas Meter Temp		Sample Box Temp.	Impinger Temp.
							Inlet	Outlet		
Port B 1	1551	0	860°	0.120	1.20	1809.90	548	548	250°	77°
2	1601	0	860	0.152	1.50	1817.30	550	548	260	80
3	1611	0	860	0.200	2.03	1824.90	558	550	280	82
4	1621	0	860	0.050	0.51	1833.90	558	550	290	80
5	1631	0	860	0.050	0.51	1838.75	552	550	300	80
6	1641	0	860	0.080	0.80	1844.00	550	549	300	80
Port A 7	1655	0	360	0.100	1.01	1848.90	550	548	300	80
8	1705	0	860	0.100	1.01	1855.50	554	550	300	80
9	1715	0	860	0.130	1.26	1862.35	554	550	300	80
10	1725	0	860	0.040	0.41	1869.50	552	550	300	80
11	1735	0	860	0.040	0.40	1874.70	544	540	300	80
12	1742					1877.70				
NOTE: Had to shut down 12 minutes early due to 40 knot winds and rain.										

Approved Oct 73/DAPM/jb/OPR: AF/EHL

TABLE C-2

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB DC Date: 6 May 1975

Test: #2

A. Particulate: _____ Total Gain 70.01 mg

1. Filter #78 Initial Wt .7016g Final Wt .73375 Gain 32.15

2. Acetone Rinse, Front Half

Initial Wt 9.90979 Final Wt 9.94765 Gain 37.86

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 73.5 g

1. Impinger 1 - Initial Wt 584.5 Final Wt 481.5 Gain (103.0)

2. Impinger 2 - Initial Wt 602.1 Final Wt 757.8 Gain 155.7

3. Impinger 3 - Initial Wt 472.6 Final Wt 476.9 Gain 4.3

4. Impinger 4 - Initial Wt 653.9 Final Wt 670.4 Gain 16.5

5. ~~Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____~~

C.	CO ₂	O ₂	CO	Time
	<u>3.2</u>	<u>15.6</u>	<u>0.0</u>	<u>1600</u>
	<u>3.2</u>	<u>15.4</u>	<u>0.0</u>	<u>1605</u>
	<u>4.8</u>	<u>14.2</u>	<u>0.0</u>	<u>1630</u>
	<u>4.2</u>	<u>14.6</u>	<u>0.0</u>	<u>1645</u>
	<u>4.2</u>	<u>15.0</u>	<u>0.0</u>	<u>1715</u>
	_____	_____	_____	_____
	_____	_____	_____	_____

Avg: 3.92 14.96 0.0

D. Fuel Consumption: 1023 lbs/hr

Engineer Capt M. L. Sweigart #4 oil Type _____

Technician Sgt W. Conway

PARTICULATE SAMPLING DATA SHEET

Run No. 3
Date 7 May 1975

Plant Steam
Base Bolling AFB

Sample Box No. 2
Meter Box No. 3

QW/QM 0.9394
Co 0.7882

EQUATIONS

$$H = K \cdot VP$$

$$K = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co} \right]^{1/2} \frac{Tm}{Ts}$$

$$K = 15.76 \frac{Tm}{Ts}$$

Ambient Temp. 54°
Barometric Press. 29.64

Heater Box Setting Maximum
Probe Heater Setting Maximum

Probe Length Medium
Nozzle Area 7.616x10⁻⁴
Cp 0.846

Schematic of Stack Cross Section

Traverse Point Number	Sampling Time	Static Pressure	Stack Temperature	Velocity Head	Orifice Diff. Pressure	Gas Sample Volume	Gas Meter Temp Inlet	Gas Meter Temp Outlet	Sample Box Temp.	Impinger Temp.
Port B - 1 Far Side	0700	0	860	0.04	0.38	1878.00	515	513	260°	60°
2	0710	0	860	0.07	0.67	1882.05	518	514	275	60
3	0720	0	860	0.10	0.95	1887.45	520	514	280	60
4	0730	0	860	0.02	0.19	1893.50	520	515	290	60
5	0740	0	860	0.04	0.38	1896.65	520	515	300	60
6	0750	0	860	0.03	0.29	1900.55	520	515	300	60
Port A - 7 Far Side	0804	0	860	0.05	0.48	1904.10	520	515	300	60
8	0814	0	860	0.08	0.76	1908.50	520	515	300	60
9	0824	0	860	0.12	1.16	1914.00	524	518	310	65
10	0834	0	860	0.03	0.29	1920.50	524	518	310	65
11	0844	0	860	0.03	0.29	1928.00	524	518	310	65
12	0854	0	860	0.07	0.77	1928.00	524	518	310	65
	0904	0	860			1933.30				

Approved Oct 73/DAPM/jb/OPR: AF/EFL

TABLE C-3

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB Date: 7 May 1975

Test: #3

A. Particulate: _____ Total Gain 112.79 mg

1. Filter #1 Initial Wt .69309 Final Wt .72566 Gain 72.68

2. Acetone Rinse, Front Half

Initial Wt 10.27211 Final Wt 10.31222 Gain 40.11 mg

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 57.8 g

1. Impinger 1 - Initial Wt 625.5 Final Wt 662.8 Gain 37.3

2. Impinger 2 - Initial Wt 559.5 Final Wt 563.8 Gain 4.3

3. Impinger 3 - Initial Wt 467.3 Final Wt 470.5 Gain 3.2

4. Impinger 4 - Initial Wt 689.5 Final Wt 702.2 Gain 13.0

5. Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____

C.	CO ₂	O ₂	CO	Time
	<u>4.8</u>	<u>14.2</u>	_____	<u>0700</u>
	<u>4.2</u>	<u>15.2</u>	_____	<u>0725</u>
	<u>4.6</u>	<u>13.4</u>	_____	<u>0745</u>
	<u>5.0</u>	<u>13.8</u>	_____	<u>0750</u>
	<u>5.2</u>	<u>13.8</u>	_____	<u>0815</u>
	<u>5.0</u>	<u>13.4</u>	_____	<u>0830</u>
	<u>4.4</u>	<u>13.8</u>	_____	<u>0845</u>

Avg: 4.75 13.94 0.0

D. Fuel Consumption: 1056 lbs/hr

#4 oil Type

Engineer Capt M. L. Sweigart

Technician Sgt Conway

This image shows a blank, aged, cream-colored page, likely an endpaper or flyleaf of a book. The paper has a slightly textured appearance with some faint smudges and discoloration, characteristic of old paper. The page is framed by a dark border, possibly the edge of the book or a scanning artifact.

TABLE C-4

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB Date: 7 May 1975

Test: #4

A. Particulate: _____ Total Gain 83.98 mg

1. Filter #2 Initial Wt .69136g Final Wt .74051 Gain 49.15

2. Acetone Rinse, Front Half

Initial Wt 10.41029 Final Wt 10.44512 Gain 34.83 mg

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 70.0 g

1. Impinger 1 - Initial Wt 645.5 Final Wt 679.8 Gain 34.3

2. Impinger 2 - Initial Wt 616.8 Final Wt 627.6 Gain 11.0

3. Impinger 3 - Initial Wt 434.3 Final Wt 437.9 Gain 3.6

4. Impinger 4 - Initial Wt 652.8 Final Wt 673.9 Gain 21.1

5. Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____

C.	CO ₂	O ₂	CO	Time
	<u>3.4</u>	<u>14.8</u>	_____	<u>1135</u>
	<u>4.0</u>	<u>14.6</u>	_____	<u>1155</u>
	<u>4.0</u>	<u>14.8</u>	_____	<u>1215</u>
	<u>4.0</u>	<u>15.2</u>	_____	<u>1250</u>
	<u>3.8</u>	<u>14.6</u>	_____	<u>1310</u>
	<u>3.6</u>	<u>14.8</u>	_____	<u>1320</u>
	_____	_____	_____	_____

Avg: 3.8 14.8

D. Fuel Consumption: 957 lbs/hr

#4 Oil Type

Engineer Capt M. Sweigart

Technician Sgt W. Conway

PARTICULATE SAMPLING DATA SHEET

Run No. 5
Date 8 April 1975

Plant C.B. Heating
Base Bolling AFB

Sample Box No.	2
Meter Box No.	3

QW/QM	0.9394
Co	0.7882

Schematic of Stack Cross Section

EQUATIONS

$$H = K, VP$$

$$K = \left[\frac{5130 \cdot \text{Fd} \cdot \text{Cp} \cdot A}{C_o} \right]^2 \frac{T_m}{T_s}$$

$$K = 15.24 \frac{T_m}{T_s}$$

Ambient Temp. 60°F
Barometric Press. 29.79

Heater Box Setting	300°
Probe Heater Setting	Full

Probe Length	Medium
Nozzle Area	7.616×10^{-4}
Cp	0.846

[illegible]

Approved Oct 73/DAPM/jb/OPR: AF/EHL

TABLE C-5

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB Date: 8 May 1975

Test: #5

A. Particulate: _____ Total Gain 121.05 mg

1. Filter #3 Initial Wt .71524 Final Wt 80196 Gain 86.72mg

2. Acetone Rinse, Front Half

Initial Wt 10.29476 Final Wt 10.32909 Gain 34.33

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 128.55 g

1. Impinger 1 - Initial Wt 662.8 Final Wt 733.5 Gain 70.7

2. Impinger 2 - Initial Wt 563.8 Final Wt 593.3 Gain 29.5

3. Impinger 3 - Initial Wt 470.5 Final Wt 476.1 Gain 5.6

4. Impinger 4 - Initial Wt 702.2 Final Wt 724.95 Gain 22.75

5. Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____

C.	CO ₂	O ₂	CO	Time
	<u>5.2</u>	<u>11.4</u>	<u>0.0</u>	<u>0623</u>
	<u>7.0</u>	<u>11.0</u>	<u>0.0</u>	<u>0642</u>
	<u>7.0</u>	<u>11.0</u>	<u>0.0</u>	<u>0700</u>
	<u>7.0</u>	<u>11.0</u>	<u>0.0</u>	<u>0715</u>
	<u>6.8</u>	<u>11.2</u>	<u>0.0</u>	<u>0730</u>
	<u>6.8</u>	<u>11.4</u>	<u>0.0</u>	<u>0800</u>
	<u>6.0</u>	<u>11.0</u>	<u>0.0</u>	<u>0815</u>

Avg: 6.77 11.14 0.0

D. Fuel Consumption: 2096 lbs/hr

#4 Oil Type

Engineer Capt M. Sweigart

Technician Sgt W. Conway

This image shows a blank, aged, cream-colored page, likely an endpaper or flyleaf of a book. The paper has a slightly textured appearance with some faint smudges and discoloration, characteristic of old paper. The left edge of the page is bound into a dark cover, and the overall tone is warm and off-white.

PARTICULATE, MOISTURE, FUEL & GAS DATA

Project: AAF-511 Boiler #: 5

Location: Bolling AFB Date: 8 May 1975

Test: #6

A. Particulate: _____ Total Gain 117.52 mg

1. Filter #4 Initial Wt .69966g Final Wt .77997 Gain 80.31

2. Acetone Rinse, Front Half

Initial Wt 9.92188 Final Wt 9.95909 Gain 37.21mg

3. Acetone Rinse, Back Half

Initial Wt _____ Final Wt _____ Gain _____

B. Moisture _____ Total Gain 117.2 g

1. Impinger 1 - Initial Wt 679.8 Final Wt 745.0 Gain 65.2

2. Impinger 2 - Initial Wt 627.8 Final Wt 653.8 Gain 26.0

3. Impinger 3 - Initial Wt 437.9 Final Wt 442.7 Gain 4.8

4. Impinger 4 - Initial Wt 673.9 Final Wt 695.1 Gain 21.2

5. Impinger 5 - Initial Wt _____ Final Wt _____ Gain _____

C.	CO ₂	O ₂	CO	Time
	<u>7.6</u>	<u>11.4</u>	<u>0.0</u>	<u>1030</u>
	<u>7.6</u>	<u>11.4</u>	<u>0.0</u>	<u>1035</u>
	<u>6.8</u>	<u>13.0</u>	<u>0.0</u>	<u>1045</u>
	<u>5.8</u>	<u>13.0</u>	<u>0.0</u>	<u>1100</u>
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____

Avg: 6.75 12.0 0.0

D. Fuel Consumption:..... 2069 lbs/hr

#4 Oil Type

Engineer Capt M. Sweigart

Technician Sgt W. Conway

AIR POLLUTION SOURCE SAMPLING

Data Sheet 1 - Preliminary Data

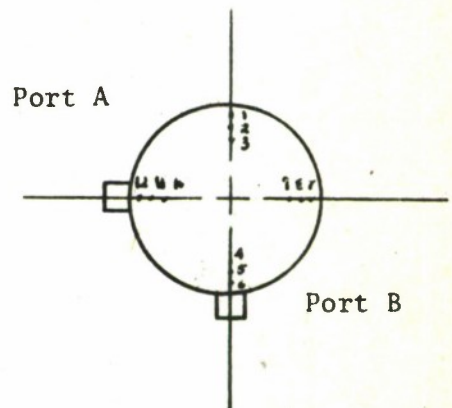
Base Bolling AFB Bldg No. 18 Boiler No. 5
 Date(s) 5 - 9 May 1975 Sampling Team USAFEHL-McClellan AFB
 Boiler Type & Make Titusville 1941
 Rated Capacity Calculated rated capacity = 44 MBTU/hr
 Type Fuel #4 fuel oil; 143,000 BTU/gal

Stack Geometry

Circular Stack: Wall thickness _____ Inside diameter 49½"
 Distance from outside of sampling port to inside diameter 5"
 Stack area 13.36ft² Number Traverses 2 No Points/Traverse 6
 Location of sampling points along traverse:

Point	% of Diam	Distance from Outer end of Nipple
6	4.4	2.17+5 = 7.17
5	14.7	7.28+5 = 12.28
4	29.5	14.60+5 = 19.60
3	70.5	34.90+5 = 29.90
2	85.3	42.20+5 = 47.20
1	95.6	47.32+5 = 52.32

SKETCH



Rectangular duct: Sketch and show dimensions:

APPENDIX D

PARTICLE DATA LABORATORIES, LTD REPORT

June 19, 1974

Washington Area Procurement Center
Department of the Air Force
Andrews Air Force Base
Washington, D. C. 20331

Attention: T.Sgt. Edgar Sam, LGPPAB

SUBJECT: Boiler Emission Tests
Bolling Air Force Base, Building 18

PDL Project G-7003, Report #G7003-1F
Contract #F49624-F4-90180

Gentlemen:

Introduction

Stack emission tests were performed on the Bolling Air Force Base heating plant boilers during the period of June 11 and June 12, 1974 to determine the effluent quality. Tests were performed to determine stack gas:

1. Temperature, velocity and volume flow
2. Moisture
3. Particulate concentration and emission rate
4. CO₂ and O₂ content by Orsat
5. Nitrogen oxide emissions rates
6. Sulfur oxides emission rates
7. Unburnt hydrocarbon emissions as methane
8. Carbon monoxide emission rates
9. Aldehyde emission rates

The purpose of the tests was to determine emission characteristics to enable Bolling Air Force Base personnel to assess compliance with District of Columbia Air Pollution codes.

Stack emission tests were performed by Meryl R. Jackson and Larr Goldfine of Particle Data Laboratories, Ltd. Operation of the boiler was performed by Bolling AFB personnel. Heating rate data was provided by Bolling AFB personnel.

Stack emission testing followed all the recognized criteria (Reference 1). The report contains an outline summary of the test procedure and test findings. Measured emission rate is compared to District of Columbia Air Pollution Code levels.

PARTICLE DATA LABORATORIES, LTD.

Attached as Appendices are complete details of all test and analytical procedures, calibration data, field test data sheets, and calculation summaries.

Description of Boilers

Boilers #5 and #6 are oil fired units burning #6 fuel. Both boilers have induced draft fans.

Summary of Test Procedures

Each of the 2 tapered stacks was tested at roof level at approximately $1\frac{1}{4}$ diameters down from the top of the stack. Two ports one on each of two mutually perpendicular diameters, were used for testing.

Each boiler was subjected to three test repetitions during which time the boiler was maintained under normal operating conditions. It was decided by Bolling AFB personnel to operate the boilers at the demand load, and not to raise the load artificially by venting steam. Each test repetition consisted of:

- A. One integrated particulate sample
- B. Two 20 minute SO_x samples
- C. Four grab NO_x samples
- D. Two integrated gas samples analyzed for CO_2 and O_2 by Orsat and CO and hydrocarbons by gas chromatography.

Stack particulate tests were performed by sampling at a number of points on each of the two diameters. Sampling was performed at each point for 5 minutes. The selection of sampling points was made in accordance with the criteria of Reference 1, as reproduced in Appendix A.

Stack gas velocity and temperature were determined using S type pitot tubes and thermocouple. Volume flow rates were determined by geometry. The volume flow rate was determined in accordance with the criteria of Reference 1, as reproduced in Appendix B.

Particulate testing was conducted using Western Precipitation, Joy Division, EPA Sampling Trains which conform to U.S. PHS requirements. Testing, sample analysis and data reduction followed criteria of Reference 1 as reproduced in Appendix C. Particulate catch included nozzle, probe and prefilter glassware washings and filter particulates. Stack gas integrated samples were taken for CO_2 and O_2 Orsat analysis.

PARTICLE DATA LABORATORIES, LTD.

Prior to shipping the equipment, the following items were checked for calibration:

- A. The "s" pitot tube mounted on the probe, but without the nozzle.
- B. The dry test meters for both the particulate and SO_x sampling trains.
- C. The calibrated orifice of the particulate train.

Calibration data are shown in Appendix D.

Integrated stack gas samples for determination of SO₂ and SO₃ were taken using midget impingers containing 80% isopropyl alcohol and 3% hydrogen peroxide as outlined in Reference 1 and reproduced in Appendix E.

Grab stack gas samples were taken using 2 liter evacuated flasks for determination of nitrogen oxides as outlined in Reference 1 and reproduced in Appendix F.

Integrated gas samples were collected for analysis of carbon monoxide and hydrocarbons as outlined in Reference 2 and reproduced in Appendix G. Detection of aldehydes was performed by gas chromatograph using a Chromasorb 102 column for separation of the aldehydes.

Particulate field test data sheets including condensate and particulate data and the calculation summaries are included in Appendix H. A single averaged gas meter temperature is provided by the Western Precipitation equipment used. This was recorded on the data sheets. Orsat data are included on these sheets.

The SO₂ and SO₃ analysis and emission data are included in Appendix I.

The NO_x analysis and emission data are included in Appendix J.

Carbon monoxide emission data are included in Appendix K.

Test data for total hydrocarbons, expressed as methane, are included in Appendix L.

Nomenclature is given in Appendix M.

Heat Input Data

Oil flow meter readings were recorded hourly by Bolling AFB personnel. A BTU specification of 147,300 BTU/gal. was used to compute heat input rates.

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Discussion of Test Findings

The results of this test series are summarized in Table 1. Emission rates are expressed in lb/MBTU for particulates, lb/hr. for sulfur dioxide, lb/MBTU for nitrogen oxides and aldehydes, and parts per million for carbon monoxide and hydrocarbons.

These emission rates are compared with District of Columbia Codes in Table 2 and show non-compliance with codes with respect to particulates (Rule 8-2:708). Sulfur oxide emissions are not subject to emission control regulations (Rule 8-2:704); however, the fuel must contain less than 1% by weight sulfur. Nitrogen oxide emissions are subject to control regulations only for boilers of input rating in excess of 100 MBTU/hr. (Rule 8-2:706). The boilers tested have capacities of less than this value and are therefore not subject to code regulations.

Unburnt hydrocarbons emissions measured as methane were detected at concentrations of 4 p.p.m., corresponding to approximately 0.15 lb/hr. emission rate. District of Columbia does not have codes limiting the emission of hydrocarbons from fuel burning equipment. Aldehyde concentrations were below the 1 p.p.m. limit of detection, which corresponds to approximately 0.12 lb/hr. emission rate.

Carbon monoxide emissions were measured as less than 5 p.p.m. on all samples collected. The District of Columbia does not publish codes relating to carbon monoxide emissions from boilers.

Discussion of Boiler Operation and Control

The data show that the boilers tested are in violation of District of Columbia codes with respect to particulate emissions only. It is our experience that oil fired boilers similar to those tested should not be in violation of codes, if functioning correctly. The following factors support our conclusion that the boilers were not functioning in an optimum manner during the test periods.

1. Visible emissions were detected from Boiler #5.
2. Carbon dioxide levels are near 3% in the stack. This indicates a high excess air ratio due to large volume of air leakage either into the combustion chamber or into the breeching and stack system. Since the stack-gas temperature are near 400°F., it is easily calculated that the boilers are operating at greatly reduced thermal efficiencies. If the leakage is into the combustion chamber, it would be expected that combustion efficiency would be poor, thus producing emissions high in particulates. This is likely to be the case since the breeching appeared to be mechanically sound.

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3. Soot balls were ejected by Boiler #6 during start-up indicating a build up of particulate deposits on the tubes and elsewhere in the system.
4. The collected particulate were carbonaceous as evidenced by their matt black appearance. If combustion had been efficient and the particulate affluent caused by a high ash fuel, the collected particulate would have been lighter in appearance.

On the basis of these factors, we believe the emissions from the boilers may be brought into compliance by improving burner efficiency and not by adding particulate emission control equipment. Factors to consider in optimizing the burners will be:

1. Excess air in combustion chamber due to induced fan operation.
2. Inability of oil burners to modulate below about 20% fuel input rate.
3. The burner efficiency of the two boilers is different as indicated by the test results. Since both burners are nominally identical, this difference may be important in indicating some of the sources of poor operation of the burners.

Recommendations

It is recommended the following actions be taken to achieve compliance with District of Columbia air pollution codes.

1. Optimize burner efficiency.
2. Perform preliminary tests to show the degree of improvement in efficiency and to aid optimization. This will improve thermal efficiency of the boilers.
3. Evaluate the need for the ID fans.
4. Clean the boilers prior to the official compliance test.
5. Re-perform a full compliance test for particulate emissions.

Particle Data Laboratories has the capabilities to perform these functions and would be keen to assist in this necessary further work. In addition, it is recommended a thermal efficiency test be performed on each boiler to indicate the further improvement which may be made in this area.

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Conclusions


Emission tests have been performed on Boilers #5 and #6 at Bolling AFB to assess emission quality. Particulate emissions fail to comply with District of Columbia air pollution regulations. Recommendations have been made for action to correct this deficiency.

Observations indicate the boilers are probably operating at very low thermal efficiency which could be upgraded by process optimization.

Particle Data Laboratories is pleased to have been of service to Bolling Air Force Base and look forward to further opportunities to be of service.

Respectfully submitted,

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Meryl R. Jackson
President

Enclosures

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TABLE 1

Summary of Emission Data

Boiler #	5	6
Particulates	.157	.161
Emission Rate	.177	.150
lb/MBTU	.191	.136
Average	.175	.149
Sulfur Dioxide	14.078	23.815
lb/hr	15.846	11.777
	17.250	20.397
	18.322	21.347
	25.935	16.382
	23.292	12.327
Average	19.121	19.008
Nitrogen	.250	.194
Oxide	.191	.198
lb/hr	.057	.203
	.187	.189
	.260	.198
	.188	.144
	.185	.086
	.116	.175
	.209	.139
	.262	.187
	.090	.198
	.218	.141
Average	0.184	0.171
Hydrocarbons	4	5
as methane p.p.m.	5	5
	5	4
	4	-
	4	4
	4	4
Average	4	4
Aldehydes p.p.m.	<1	<1
Carbon Monoxide p.p.m.	<5	<5

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TABLE 2

Comparison of Emission Rates with Code Levels

	<u>Emission Rate</u>	<u>Averaged Heat Input Rate</u>	<u>Allowable Emission Rate</u>
<u>Particulates</u>			
<u>Boiler #5</u>	.157 lb/MBTU	16.940 MBTU/hr	.090 lb/MBTU
	.177	16.301	.091
	.191	15.123	.092
<u>Boiler #6</u>	.161	16.350	.090
	.150	17.038	.090
	.136	16.940	.090
<u>Sulfur Dioxide</u>			
<u>Boiler #5</u>	19.121 lb/hr	No codes on emission, however code 8-2:704 prohibits use of oil having sulfur contents in excess of 1% by weight.	
<u>Boiler #6</u>	19.008 lb/hr		
<u>Nitrogen Oxide</u>			
<u>Boiler #5</u>	0.184 lb/MBTU	No codes on emissions for boiler of input capacity less than 100 MBTU/hr (8-2:706).	
<u>Boiler #6</u>	0.171 lb/MBTU		
<u>Unburnt Hydrocarbons</u>			
<u>Boiler #5</u>	4 p.p.m.	No code on emissions from boiler	
<u>Boiler #6</u>	4 p.p.m.		
<u>Aldehydes</u>			
<u>Boiler #5</u>	<1 p.p.m.	No codes on emissions of aldehydes from boilers.	
<u>Boiler #6</u>	<1 p.p.m.		
<u>Carbon Monoxide</u>			
<u>Boiler #5</u>	<5 p.p.m.	No codes on emissions of carbon monoxide from boilers.	
<u>Boiler #6</u>	<5 p.p.m.		

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Reference 1. Federal Register 36, #247, Part II, December 23, 1971.

Reference 2. Measurement of Carbon Monoxide ATP-2, Illinois EPA
(Nov. 1972).

Appendix A. Sample and Velocity Traverses for Stationary Sources.

Appendix B. Determination of Stack Gas Velocity.

Appendix C. Determination of Particulate Emissions from Stationary Sources.

Appendix D. Equipment Calibration Data.

Appendix E. Determination of Sulfur Dioxide Emissions from Stationary Sources.

Appendix F. Determination of Nitrogen Oxide Emissions from Stationary Sources.

Appendix G. Measurement Methods for Carbon Monoxide.

Appendix H. Particulate Field Test Data Sheets.

Appendix I. Sulfur Oxide Test Data.

Appendix J. Nitrogen Oxide Test Data.

Appendix K. Carbon Monoxide Test Data.

Appendix L. Hydrocarbon Test Data.

Appendix M. Nomenclature.